10146

LAKE SHAFER
PRELIMINARY INVESTIGATION

Submitted To:

MONTICELLO CHAMBER OF COMMERCE
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TABLE OF CONTENTS

TABLE OF CONTENTS

(Concluded)

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

International Science & Technology, Inc. (IS&T) conducted a preliminary investigation into the accelerated accumulation of sediment in Lake Shafer for the Monticello Chamber of Commerce (MCC) under a grant from the Indiana Department of Natural Resources' (IDNR's) Lake Enhancement Program. This report presents a summary of the findings and recommendations for future actions in implementing a restoration plan for the lake.

INTRODUCTION

Lake Shafer is an approximately 1400-acre reservoir created in 1922 when Norway Dam was constructed on the Tippecanoe River just north of Monticello, Indiana. Lake Shafer and its sister reservoir, Lake Freeman (formed by the construction of Oakdale Dam, approximately 8 miles downstream), provide hydroelectrical power and recreational opportunities to the communities of North Central Indiana.

The headwater of the Tippecanoe River is on the northern edge of Whitley County in Little Crooked Lake. The river basin consists of 563 miles of streams, 509 miles of ditches, and 950 miles of intermittent streams draining 1730 square miles of land. There are also 206 lakes and ponds within the basin. Uses of the waters include hydroelectric power generation at Norway and Oakdale dams, swimming, fishing, boating, and water skiing. Estimates of the value of Lake Shafer to the state in tax revenues alone are in the neighborhood of $5 million.

Because of its position in the Tippecanoe River drainage basin, Lake Shafer functions as a natural sediment trap for Lake Freeman. The sediments reduce the storage capacity of the reservoir, impair recreation, and transport nutrients and pollutants from the upper watershed to the lake where they can affect changes in water quality and biological communities. In recent years the storage capacity of the reservoir has been reduced and access to large areas of the lake has been severely restricted by the development of extensive shoals and bars. These changes not only impair the use and function of the reservoir, but ultimately also lead to economic losses for the surrounding communities.

As a preliminary investigation, the objectives of this project may be summarized as follows:

- Collect and evaluate all available information and data that are relevant to sediment problems in the lake.
- Compile and present the relevant data within the framework of a computerized geographic data index (GDI).
- Determine the current status of Lake Shafer with respect to sediment accumulation.
- Identify deficiencies in the current knowledge about the Lake and the sources and nature of sediment problems.
- Identify potential mitigation and restoration techniques.
- Recommend future plan of action and identify potential sources of funding for implementation.

PERTINENT DATA REVIEWED

A number of sediment surveys have been conducted in Lake Shafer since its creation in 1922. Observations of sediment accumulation and water depth have been documented in 1923, 1940, 1954, 1960, 1983, 1986, and 1988. The level of documentation and detail varies significantly among these studies. Table E-1 summarizes the relevant data from these studies.

The most dramatic changes were noted between the 1960 and 1983 surveys. There were a number of areas in the lake where only two to three feet of water were observed in the 1983 survey but the 1960 survey reported 10 to 15 feet. The greatest depth loss had occurred in the reach between Big Monon Creek and the Lowes Bridge. The source of sediments in this reach appears to be Big Monon Dredge Ditch. It was concluded that sediment accumulation is getting worse and that the major sediment trapping areas seem to be moving downstream. "The upper reaches have received about as much sediment as they are going to keep," and an equilibrium of sorts has been reached between sedimentation and ice scour. The problem may be expected to continue moving downstream.

TABLE E-1. SUMMARY OF SEDIMENT SURVEYS CONDUCTED IN LAKE SHAFER.

Year	Interval (Yrs)	Capacity (Ac-ft.)	Capacity Lost (Ac-ft.)	Annual Loss (Ac-ft.)	Annual Accumulation Rate (Ac-ft./Mi ^{2})	(Tons/Mi ^{2})	(Tons/Ac)
1923	-	14,722	-	-	-	-	-
1940	17	14,041	681	40.1	0.023	37.6	0.06
1954*	14	n/a	n/a	n/a	n/a	n/a	n/a
1960	6	13,018	1,023	51.2	0.029	48.0	0.08
1984*	24	n/a	n/a	n/a	n/a	n/a	n/a
1986	3	11,000	2,018	77.6	0.045	72.9	0.11

* = Quantitative data were not reported.
n/a = Not Applicable.

The White County Soil & Water Conservation District Board and the SCS conducted an analysis of the Big Monon Dredge Ditch watershed in 1983. The average sheet and rill erosion rate was 2.43 tons per acre per year (tons/ac-yr.) from contributing (i.e., erodible) areas. The weighted average erosion rate for all lands in the basin was 1.05 tons/ac-yr, which compares very favorably with the "T", or tolerable soil erosion limit of 5.0 tons/acre/year. Sediment yield was estimated at 0.54 tons/ac-yr. It was concluded that farms in the Big Monon Dredge Ditch watershed are being well managed, and that erosion control in this basin is probably not the answer to Lake Shafer's problems.

Suspended sediment and discharge data were collected by the USGS and IDNR at a partial record station on the Tippecanoe River near Ora. This station represents the uppermost 49 percent of the Lake Shafer watershed. The estimated average sediment discharge was approximately 0.05 tons/ac-yr, considerably lower than the state-wide partial record average of 0.25 tons/ac-yr. There was no indication of a significant temporal trend in sediment transport at the Tippecanoe River station.

Three erosion potential analyses have been conducted and are available for counties in the Lake Shafer watershed. An analysis was conducted by Indiana DNR in 1981 or 1982 using soil association characteristics to develop a distribution of water erosion index values for the Lake Shafer watershed. The results indicate that approximately 70 percent of the watershed is composed of soils that have a slight to negligible potential for water erosion. The remaining 30 percent of the basin is characterized by a slight to moderate erosion potential.

Indiana DNR published a regional analysis of various aspects of water resources, including soil erosion potential. Approximately 432,600 acres, or 35 percent of the watershed is reported as having a high potential for sheet and rill erosion. The highest potential is in the counties in the upper portion of the watershed.

SCS and IDNR have conducted erosion studies in Northeastern and Northwest-Central Indiana. These studies indicate that 365,387 acres, or 32.9 percent of the counties covered within the Lake Shafer watershed are dominated by sheet, till, or gully erosion.

DISCUSSION

The historical data clearly indicate that capacity in Lake Shafer is being lost and recreational uses are being impaired. Moreover, costly damage is being sustained by shoreline structures and properties as a result of the increasing occurrence and magnitude of ice jams during the spring thaw. The problem appears to be moving steadily downstream towards Norway Dam. However, the evidence indicates that sediment loading from the upper one-half of the watershed to the Tippecanoe River has remained relatively constant over time.

There were several observations in the historical sediment surveys suggesting that Big Monon Dredge Ditch is a major source of sediment loading to Lake Shafer. An estimate of the total annual sediment contribution from the Big Monon Dredge Ditch sub-basin was calculated at 63,590 tons/yr, or nearly half of the estimated annual sediment accumulation in Lake Shafer (i.e., 121,933 tons). Although excessive soil erosion (relative to "T") is not evident either in the Big Monon Dredge Ditch sub-basin, or in the watershed as a whole, the erosion potential analyses indicate that approximately one-third of the watershed is subject to significant erosion. Erosion rates in specific areas within the watershed may be excessive and amenable to reduction through land treatment practices.

The rate of sediment accumulation in Lake Shafer increased 25 percent from 0.06 to 0.08 tons/ac-yr. over the 20 years between the 1940 survey and 1960. In the 26 years between 1960 and 1986 the mean rate increased 27 percent, from 0.08 to 0.11 tons/ac-yr. It appears that there has been a relatively steady increase, or acceleration, in the rate of sediment accumulation in Lake Shafer since its creation.

Apparent sedimentation rates have increased in Lake Shafer as the delivery rate of suspended sediment from the Tippecanoe River has increased. This increase may be attributed to a progressive filling of natural sediment traps in the drainage basin. As the upstream traps become filled to capacity, the material they would have intercepted is transported downstream to the next trapping area. Downstream sediment traps are filled at an accelerated rate as loading rates increase. The net effect is an increasing rate of sediment delivery to, and capacity loss in, Lake Shafer.

The evidence shows that sediment loading in the Tippecanoe River is within the normally acceptable range, and in fact is on the lower end of the range observed by the USGS for rivers in the state. Moreover, the sediment discharge observed for the Tippecanoe River is consistent in magnitude with the rates of sediment accumulation observed in the lake, although these rates appear to be increasing over time.

CONCLUSIONS

The observed sediment accumulation in Lake Shafer is the result of a natural process that has not been accelerated by increasing or excessive erosion in the Tippecanoe River watershed. The observed increase in the rate of sediment accumulation in Lake Shafer appears to be the result of the loss of sediment trapping capacity in the watershed. The mouths of Big Monon Creek and Hoagland Ditch are examples of historically effective sediment traps.

An effective restoration program for Lake Shafer must address the two problems of increased sediment transport to the lake and unacceptable volumes of accumulated sediment already in the lake. The former problem may be addressed by ensuring that erosion control practices are implemented to the extent practical in the watershed, through the renovation of historically effective sediment traps, and through the design and construction of new sediment traps.

The only solution to the accumulation of sediment that currently exists in Lake Shafer is a large-scale dredging project. Hydraulic dredging will probably provide the most cost effective method for removing the substantial volumes of sediment that will be required to be removed from Lake Shafer. The cost of dredging the lake is anticipated to be in the range of $8.5 million and $14 million, based on a likely range of unit costs from $1.50 to $2.50 per cubic yard.

Sediment removal requirements for the renovation of existing sediment traps and construction of new traps in the watershed is impossible to estimate at this time. However, if it is assumed that the accumulated material in the lake (i.e., approximately 3,500 ac-ft.) would have been intercepted by these traps if they had been in place and working, then an equivalent amount of money may be required for this portion of the restoration project as for the in-lake effort. This is probably a conservative estimate.

RECOMMENDATIONS

The next step in the restoration of Lake Shafer should be a feasibility study with the following component tasks:

- Conduct a detailed review of soil erosion rates in the watershed to identify "hot-spots" where erosion is a problem and treatments may be implemented.
- Identify natural sediment traps and sites for constructed sediment traps in the watershed.
- Develop a watershed sediment transport model to serve as the basis for evaluating the placement of sediment traps and the sediment accumulation rates that may be expected in Lake Shafer. This effort will require the collection of suspended sediment data at critical locations in the watershed over a wide range of flow conditions.
- Develop estimates of trapping capacities, efficiencies, and rates for the identified sediment traps.
- Define an acceptable maintenance program for Lake Shafer, including intervals between major dredging operations.
- Develop estimates of sediment removal volume required to restore Lake Shafer's recreational value and provide sediment assimilation capacity over the maintenance interval.
- Collect lake and river basin sediment samples and analyze for EP toxicity.
- Collect lake sediment samples and quantify settling characteristics.

- Develop preliminary design requirements for the disposal site.
- Identify and evaluate suitable site(s) for settling basin and dredge spoil disposal. Slurry pipe routes should be included in this evaluation.
- Identify potential dredging contractors and develop confident estimates of costs for dredging lake and sediment traps.
- Identify all required permits for the proposed dredging program, contact the responsible agencies/authorities, and assemble required information to obtain permits.
- Identify, contact, and pursue potential sources of funding, including state and Federal grant programs, user fees, and bond issues.
- Design a monitoring program for assessing progress and environmental impact during and after the dredging.
- Develop a schedule for final design and implementation of the project.
- Establish funding package with commitments from contributing parties.

The second phase of the restoration will be the design of the dredging and sediment trap construction. Final design efforts will include detailed layouts of the slurry pipeline, disposal site, and all necessary road improvements and modifications. Similarly detailed specifications will be developed for all sediment traps. The design effort will include finalization of the dredging and construction schedule, submittal of all required permit applications, receipt of approvals for these permits, and issuance of a request for bids to interested dredging companies. A request for proposals should be also issued for monitoring activities during and after the dredging effort.

The last phase of the restoration program will be the actual sediment removal and sediment trap renovation/construction. A certain amount of final planning modifications should be anticipated after a dredging contractor has been identified. These activities may include development of a contractors work plan and safety plan, and finalization of monitoring protocols.

It is essential that a post-dredging monitoring program be planned and implemented as part of the restoration effort. The data collected will provide a means of measuring the success of the dredging activities and assessing the long-term response of the lake to the effort.

Lake restoration efforts are costly, and among the technologies used in restoration projects, dredging is one of the most expensive. Therefore it is crucial to the success of the Lake Shafer restoration that sources of funding be identified early in the planning process. Funding sources for restoration projects are available at the Federal, state, and local level. Most Federal grants or awards require a matching funds arrangement where the recipient is expected to provide some fraction of the total cost of restoration. Local funding sources include tax assessments, users fees, private foundations that foster certain aspects of lake management, and local organizations that can either provide contributions or sponsor fund-raising activities.

There are a number of institutional options that should be investigated as means of providing planning, funding, and political coordination in support of a restoration effort for Lake Shafer. One strategy is the formation of a Tippecanoe River basin commission, similar to those established for the Kankakee, St. Joseph, and Maumee River basins to address flooding issues. Another potential option would be the establishment of a Conservancy District under the IDNR Conservancy District Act. There are approximately 70 such districts currently in the state.

LAKE SHAFER PRELIMINARY INVESTIGATION

DRAFT REPORT

SECTION 1. INTRODUCTION

International Science & Technology, Inc. (IS&T) conducted a preliminary investigation into the accelerated accumulation of sediment in Lake Shafer for the Monticello Chamber of Commerce (MCC) under a grant from the Indiana Department of Natural Resources' (IDNR's) Lake Enhancement Program. This report presents a summary of the findings and recommendations for future actions in implementing a restoration plan for the lake.

1.1 LAKE SHAFER

Lake Shafer is an approximately 1400-acre reservoir created in 1922 when Norway Dam was constructed on the Tippecanoe River just north of Monticello, Indiana (Figure 1). Lake Shafer and its sister reservoir, Lake Freeman (formed by the construction of Oakdale Dam, approximately 8 miles downstream), provide hydroelectrical power and recreational opportunities to the communities of North Central Indiana.

Within the Indiana Lake Classification System, Lake Shafer is currently classified as a Class Two (moderately eutrophic) lake. Moreover, the lake has been classified as a Group III lake within the Indiana Department of Environmental Management (IDEM) Lake Management Plan scheme of seven major groupings. Management priority for Group III lakes is placed on the prevention of further deterioration through the reduction of external nutrient inputs (loadings). The Management Plan allows for in-lake restoration in certain cases.

1.2 PROBLEM DESCRIPTION

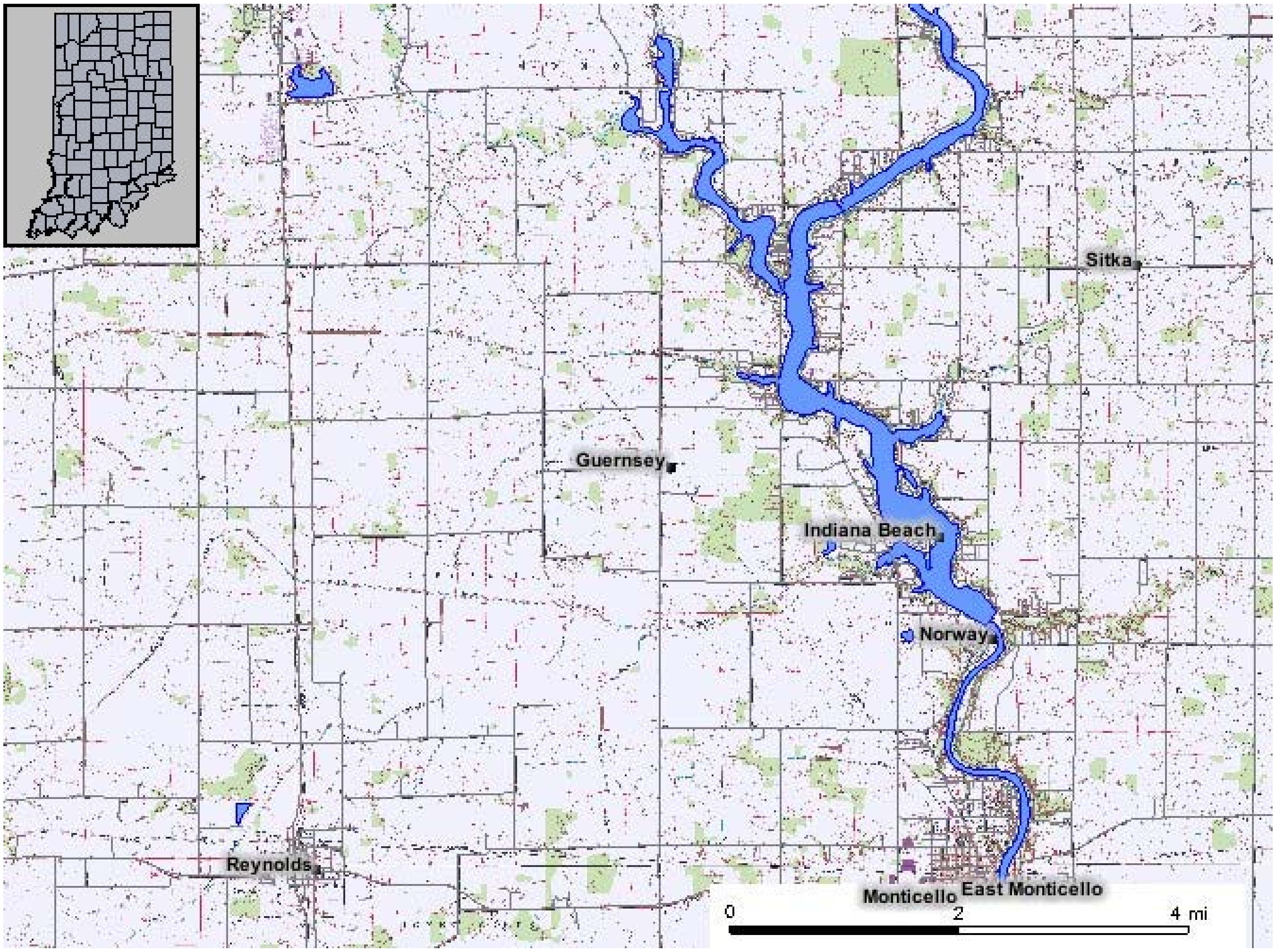
Because of its position in the Tippecanoe River drainage basin, Lake Shafer functions as a natural sediment trap for Lake Freeman. The suspended sediments transported by the Tippecanoe River and its tributaries are deposited as water velocities decrease upon entry into the reservoir. These sediments reduce the storage capacity of the reservoir, impair recreation, and transport nutrients and pollutants from the upper watershed to the lake where they can affect changes in water quality and biological communities.

Although sediment accumulation is a natural process in most reservoirs, there has been evidence that the rate of accumulation in Lake Shafer has increased substantially in recent decades. The storage capacity of the reservoir has been reduced and access to large areas of the lake has been severely restricted by the development of extensive shoals and bars. Moreover, these shallow areas restrict the passage of spring ice flows, which form ice dams blocking the upper portions of the lake and result in extensive damage to shoreline structures, such as piers and docks. These changes not only impair the use and function of the reservoir, but ultimately also lead to economic losses for the surrounding communities.

1.3 PROJECT OBJECTIVES

As a preliminary investigation, the objectives of this project may be summarized as follows:

- Collect and evaluate all available information and data that are relevant to sediment problems in the lake.
- Compile and present the relevant data within the framework of a computerized geographic data index (GDI).
- Determine the current status of Lake Shafer with respect to sediment accumulation.
- Identify deficiencies in the current knowledge about the Lake and the sources and nature of sediment problems.
- Identify potential mitigation and restoration techniques.
- Recommend future plan of action and identify potential sources of funding for implementation.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Norway
Reynolds
Monticello
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This report presents the results of the investigation. Section 2 summarizes the literature and data review that was conducted. Section 3 presents a characterization of the Lake Shafer watershed. Section 4 presents a discussion and interpretation of the reviewed data as it pertains to the sediment accumulation problem in the lake. Section 5 is a summary of appropriate restoration alternatives. Section 6 presents a summary of recommendations for further action in undertaking a restoration program, including a consideration of potential sources of funding that may be available to the MCC.

SECTION 2. LITERATURE AND DATA REVIEW

This section presents a summary of relevant data and literature that were identified, acquired, and reviewed for this project. This material was collected through a comprehensive search at the offices of county, state, and Federal agencies, as well as academic institutions throughout the state.

2.1 DATA IDENTIFICATION

The information collection process was initiated with telephone interviews with individuals in the various government and university offices. Appendix A presents a listing of all offices, agencies, and institutions contacted during this survey.

When the interview resulted in the identification of potentially relevant data or literature (e.g., reports, papers, etc.) requests where made for copies to be sent to IS&T. A substantial amount of the water quality and environmental data were located in files that could not be copied en masse. In these cases, visits were arranged to the offices where the files resided to review and index the data on-site. Index information, consisting of an abstract and a station listing for each file was entered on a laptop computer. This information provided the basis for the data review, as well as the computer-based geographic data index system ("TIPPE") that was produced as part of the project.

Table 1 presents a listing of all data and studies that were reviewed during this project. Appendix B contains abstracts of each study and data set, including the names, addresses, and telephone numbers of individuals to contact for access to the data and further information. A subset of the reviewed data consisted of studies and data sets that were relevant to the specific problem of sediment transport and accumulation in the Tippecanoe River watershed. Each element of this subset was analyzed and evaluated in detail, and is summarized in the following section.

TABLE 1. LIST OF STUDIES, DATA SETS, AND INFORMATION REVIEWED.

WATER QUALITY DATA

IDEM Stream Segment 27 Survey

IDEM Stream Segment 30 Survey

IDEM Stream Surveys

IDEM Kosciusco County Stream Report

Mill Creek Bacteriological Survey

Pulaski County Stream Surveys

National Eutrophication Survey

IDEM Lake Data

STORET Lake Data

Kosciusco County Lake Data

Lake Shafer Bacteriological Survey

Lake Maxinkuckee Surveys

SEDIMENTATION STUDIES AND DATA

Lake Shafer Sediment Surveys: 1923 and 1940

IDNR Lake Shafer Sediment Survey - 1954

IDNR Lake Shafer Sediment Survey - 1983

IDNR Lake Shafer Sediment Survey - 1986

USGS Stream Sediment Data

Lake Lemon Sedimentation Study

Big Monon Dredge Watershed Study

"Suspended Sediment Characteristics of Indiana Streams."

BIOLOGICAL DATA

Tippecanoe River Stream Surveys: 1972 and 1974

Lake Shafer Fish Surveys: 1975 and 1977

Lake Shafer, Lake Freeman, and Tippecanoe River Fish Surveys: 1976-81

Lake Shafer and Tippecanoe River Watershed Fish Stocking Studies: 1983-85

IDEM Fishkill Data

TABLE 1. (Concluded)

LANDUSE DATA

Miscellaneous Land Use Data (including erosion)

1988 Conservation tillage practices by county.

1985 acres in cropland, pasture, & forest for Starke County.

1981 acres in cropland, pasture, & forest for Jasper, Newton, Pulaski, Starke, White, Fulton, Marshall, and Kosciusco counties.

1978 acres in cropland, pasture, & forest for Elkhart, Laporte, St. Joseph, Marshall, and Kosciusco counties.

1954 - 1978 acres in cropland, pasture, & forest for Marshall County

Erosion Potential Summaries

Northeast Indiana Erosion Study

County Soil Surveys

Soil and Water Conservation Needs Inventory

Water Resource Summary

Natural Resources Inventory

NPDES Permits

Feedlot Permits

Coal and Mineral Operations

TOXIC CHEMICALS DATA

IDEM Lake Fish Tissue Analyses

IDEM Fish Tissue and Sediment Samples

IDEM Chemical Spills Records

Warsaw Black Oxide Investigation

2.2 REVIEW OF RELEVANT DATA

This section presents reviews of each study or data set that is relevant to sedimentation in Lake Shafer. The analyses focus on the salient findings and implications of each study.

2.2.1 DNR Sediment Surveys

A number of sediment surveys have been conducted in Lake Shafer since its creation in 1922. Observations of sediment accumulation and water depth have been documented in 1923, 1940, 1954, 1960, 1983, 1986, and 1988. The level of documentation and detail varies significantly among these studies. Table 2 summarizes the relevant data from these studies.

1923 and 1940. These Soil Conservation Service (SCS) surveys are not well documented, but the results are reported in the U.S. Department of Agriculture (USDA) publication "Sediment Deposition in U.S. Reservoirs: Summary of Data Reported Through 1975." The available data include drainage area, reservoir capacity, and average annual sediment accumulation over the periods of record.

1954. The Indiana Department of Conservation, Division of Water Resources conducted a sediment survey in October, 1954. The purpose of the survey was to obtain general information about sedimentation in the lake. The details of the investigation were reported by Mr. John Uhl in "Report of Sedimentation of Shafer Lake," an internal report.

The survey coincided with a lowering of the lake level of approximately 14 feet to allow repairs to Norway Dam. The survey was limited to exposed lake bottom during this drawdown. The area remaining under water corresponded to the original stream channel.

Data collection consisted of soundings and cores taken at several locations, and estimations of sediment accumulation around tree stumps and fence posts. There are no maps of sampling sites for this survey.

TABLE 2. SUMMARY OF SEDIMENT SURVEYS CONDUCTED IN LAKE SHAFER.

Year	Interval (Yrs)	Capacity (Ac-ft.)	Capacity Lost (Ac-ft.)	Annual Loss (Ac-ft.)	Annual Accumulation Rate		
					(Ac-ft./Mi ^{2})	(Tons/Mi ^{2})	(Tons/Ac)
1923	-	14,722	-	-	-	-	-
1940	17	14,041	681	40.1	0.023	37.6	0.06
1954*	14	n/a	n/a	n/a	n/a	n/a	n/a
1960	6	13,018	1,023	51.2	0.029	48.0	0.08
1984*	24	n/a	n/a	n/a	n/a	n/a	n/a
1986	3	11,000	2,018	77.6	0.045	72.9	0.11

* = Quantitative data were not reported.
n/a = Not Applicable.

An attempt was made during this study to collect sediment surface elevations for a contour map, but the soft sediments prevented foot travel. The author noted that no surface contours were ever measured prior to construction of the reservoir.

In general, the investigators observed a small amount of sedimentation relative to the age of the reservoir. The average sediment thickness over the entire lake was estimated to be 6 inches.

Two areas were observed to have substantial sediment accumulations: Honey Creek and Hoagland Ditch (Figure 1). The enlarged mouths of these two streams apparently served as sediment traps for discharges entering the lake.

The mouth of Honey Creek was estimated to have a total of 8 ac-ft. of sediments accumulated in it, ranging in depth from 0 to 18 feet. It was concluded that the main body of the lake had been spared heavy silt loadings as a result of sediment trapping here.

Very little sediment accumulation was noted at the small creek entering Lake Shafer 500 yards south of Hoagland Ditch. Erosion did not appear to be a significant factor. This intermittent tributary was typical of several small gullies around the lake.

Large amounts of sediment were observed in Hoagland Ditch above the bridge crossing it. The sediments consisted of sands, silts, and dead vegetation. A significant portion of the shoal areas may have been the result of vegetative growth. The greatest sediment depth observed in the area immediately above the bridge was 14 feet. The variability in composition of the sediments made it impossible to estimate the volume of new sediment. The segment of Hoagland Ditch below the bridge did not experience a heavy silt accumulation.

Sediment accumulation in Big Monon Creek below the Bedford Church bridge was observed to be slight (less than 8 inches). The sediments were observed to be "very black, highly carbonaceous, with fine sand predominantly overlain with silts." There were no sand bars observed below the bridge.

There were no visible accumulations of silt near the mouth of Big Monon Ditch (identified as Ketman Ditch), although this stream was observed to experience high flows of very muddy water. The plume was visible a quarter mile below the point of discharge into the lake (Tippecanoe River).

Estimates of 9,000 ac-ft and 20 ac-ft/yr were calculated for reservoir capacity and annual loss, respectively. Unfortunately these values are only representative of that portion of the bottom that was exposed during the drawdown. No measurements were taken of the remaining stream channel and as a result it is not possible to estimate total reservoir capacity from this survey. Although the anecdotal information is valuable in documenting the qualitative extent of sedimentation in the lake, this survey does not provide quantitative data for estimating sedimentation rates.

1960. The U.S. Geological Survey (USGS) and Indiana Department of Conservation conducted a hydrographic survey of Lake Shafer during the period of June, 1959 to May, 1960. Depth data were collected using a fathometer and tag lines strung across the lake. The resulting data appear on the USGS Monticello North quad sheet. The mapped contours indicate an estimated reservoir volume of 13,118 ac-ft and a surface area of 1,291 acres.

1983. A limited bathymetric survey was conducted by IDNR with assistance from local residents: Bruce Clear, Bill Luse, and Walt Steveson. An in-house report, dated August 26, 1983, was prepared by Mr. James T. Strange and submitted to Rex R. Stover describing the results of the survey. The report also presents a summary and analysis of the 1954 sediment survey.

The 1983 survey covered the area between Hoagland Bay and Big Monon Ditch, and consisted of water depth measurements taken with a fish-finder fathometer. Depths were measured at points along longitudinal transects in the lake and plotted on a copy of the USGS Monticello North quad sheet. The objective of the survey was to compare measured water depths against those indicated on the quad sheet to estimate sediment accumulation at selected locations over the period of 1960 to 1983. Average depth loss was calculated over four defined segments: Hoagland Bay to Big Monon Creek (4.5 ft.), Big Monon Creek to Lowes Bridge (7.2 ft.), Lowes Bridge to Carnahan Ditch No. 2 (5.7), and Carnahan Ditch No. 2 to Big Monon Ditch (1.5 ft.). There were a number of areas where only two to three feet of water were observed in the 1983 survey but the 1960 survey reported 10 to 15 feet.

The author concluded that the greatest depth loss had occurred in the reach between Big Monon Creek and the Lowes Bridge and that the source of sediments in this reach was Big Monon Dredge Ditch. These sediments stay in suspension in the segment of lake between the confluence of Big Monon Ditch and the Lowes Bridge. An important assumption was that this upper segment of lake had been filled to effective capacity with sediment long ago and the sedimentation process moved downstream to below the Lowes Bridge.

There were many places above Hoagland Bay where the water was observed to be less than three feet deep. This results in the formation of ice dams during the spring thaw period. These ice jams direct the river into intense localized flows that erode the lake bottom and promote the transport of sediments downstream. A minimum depth of five feet was suggested to prevent ice jams. Several pictures were taken and included in the report to document the damage done by ice jams to the shoreline.

The author concluded that sediment accumulation is getting worse and that the major sediment trapping areas seem to be moving downstream. "The upper reaches have received about as much sediment as they are going to keep," and an equilibrium of sorts has been reached between sedimentation and ice scour. The problem may be expected to continue moving downstream.

Several ideas were presented for future discussion:

- There are some fields near the upper reaches of the lake that may be suitable for dredge spoil disposal.
- The solution to the sedimentation problem should be developed before any dredging is undertaken.
- Sedimentation is exacerbating the ice damage problem.
- One solution may be to construct sediment trapping basins at the mouths of the major tributaries, especially Big Monon Ditch.
- Local interests must be included in any mitigation effort.

The 1983 study does not provide sufficient data to estimate reservoir capacity for caparison with other years.

1986. The most extensive sediment survey of Lake Shafer was conducted in October and November, 1986 by IDNR. The results were reported in a Department Memorandum dated December 5, 1986 to Mike W. Neyer, Assistant Director, Division of Water by James T. Strange, Engineering Geology Section. The survey was conducted during a drawdown of the lake to service Norway Dam. The extent of the survey was limited because the period of drawdown to lowest elevation was relatively short (i.e., five days).

Sediment thickness and composition were observed using a hand auger and steel hand probe. Aerial photographs were taken and used to define the location and extent of the major sediment deposits exposed during the drawdown. An arbitrary depth of one foot was assigned to unexposed sediments in the main channel. Documentation of the survey was very complete, including detailed volume calculations. The estimate of accumulated sediments was 3,756 ac-ft., or 6,058,600 yd^3.

A comparison of the 1923, 1940, 1960, and 1986 reservoir surveys was presented in the report (Figure 2). The author concluded that the rate of sedimentation had accelerated between 1960 and 1986. The findings were generally consistent with the 1983 survey in that most of the

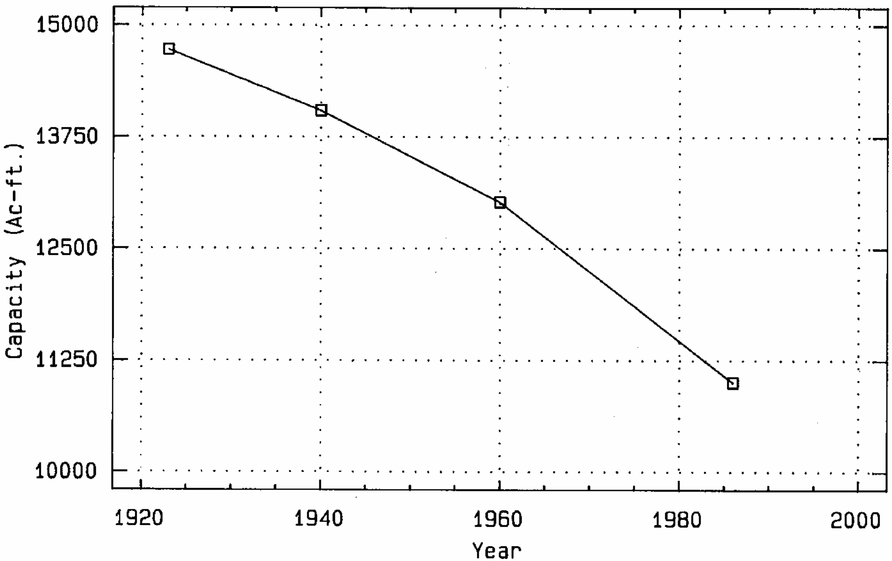


Figure 2. Reported Capacity of

Lake Shafer (Strange, 1986).

identified problem areas were upstream of Lowes Bridge, and the problem was observed to be getting progressively worse at a faster rate.

2.2.2 Big Monon Dredge Watershed Study

The White County Soil & Water Conservation District Board and the SCS conducted an analysis of the Big Monon Dredge Ditch watershed in response to the results of the 1983 IDNR sediment survey of Lake Shafer. In the 1983 report, it was suggested that Big Monon Dredge Ditch was the major source of sediment to the lake.

Sheet and rill erosion were estimated for each county in the 117,760 acre watershed (11 percent of the total Lake Shafer drainage basin). The average erosion rate was 2.43 tons per acre per year (tons/ac-yr.) from contributing (i.e., erodible) areas. The weighted average erosion rate for all lands in the basin was 1.05 tons/ac-yr. This compares very favorably with the "T", or tolerable soil erosion limit of 5.0 tons/acre/year. It was estimated that only 51 percent of the total erosion would be delivered to receiving streams, resulting in an estimate of sediment yield of approximately 0.54 tons/ac-yr. It was concluded that farms in the Big Monon Dredge Ditch watershed are being well managed, and that erosion control in this basin is probably not the answer to Lake Shafer's problems.

2.2.3 USGS Stream Sediment Data

Suspended sediment and discharge data were collected by the USGS and IDNR at a number of continuous and partial record stations throughout Indiana. An analysis of these data are presented in the USGS Open-File Report 87-527 "Suspended Sediment Characteristics of Indiana Streams, 1952-1984" by C.G. Crawford and L.J. Mansue (1988). These data are available through the U.S. Environmental Protection Agency's STORage and Retrieval system (STORET).

One of the partial record stations was on the Tippecanoe River near Ora. This station has a drainage basin of 856 square miles, representing the uppermost 49 percent of the Lake Shafer watershed. A total of 48 observations were available over the period of 1968 to 1979. The flow weighted mean suspended sediment concentration was 30 mg/l, corresponding to an estimated average sediment discharge of 75 tons/day, or approximately 0.05 tons/ac-yr. This rate was considerably lower than the partial record average of 0.25 tons/ac-yr. There was no indication of a significant temporal trend in sediment transport at the Tippecanoe River station over this study period.

Predictive models were fitted to the data. Sediment transport at the Tippecanoe station was described as a function of stream discharge by a second-order polynomial ($R^2 = 0.74$). In addition, an empirical model was developed predicting suspended sediment yield as a function of watershed characteristics, such as percent forested land, percent open water, channel slope, annual excess precipitation, soil-runoff coefficient, and peak unit discharges at 2, 10, and 25-year recurrence intervals.

Some general observations documented in this report include the following:

- The majority (up to 97 percent) of the suspended sediment loads occurred during relatively infrequent very large flows.
- There was a poor correlation between suspended sediment concentration and stream flow, probably as a result of the fine-grained particles that constitute the major portion of suspended sediment in Indiana streams.
- Bed load discharge generally constituted less than 10 percent of total sediment load.
- There was no significant temporal trend observed in the data.

2.2.4 IDEM Lake Surveys

1975. A limnological survey was conducted on Lake Shafer on August 13, 1975 by the Indiana Department of Environmental Management (IDEM). Dissolve oxygen (DO) and temperature profiles were recorded and samples were taken at the surface, 5, 10, 15, and 23 feet. The samples were analyzed for total phosphorus (TP), soluble phosphates (PO_4), total kjeldahl nitrogen (TKN), nitrates (NO_3), and ammonia (NH_4). Average TP and TKN concentrations were 0.12 mg/l and 0.94 mg/l, respectively. These values are typical of eutrophic lakes. The nitrogen to phosphorus (N:P) ratio was approximately 8.8, suggesting a tendency towards nitrogen limitation.

Water samples were also collected from the major tributaries to Lake Shafer and analyzed for the same set of constituents as the in-lake samples. TP was highest in McKillip Ditch (0.29 mg/l), Big Monon Creek (0.19 mg/l), Honey Creek (0.17 mg/l), and the Tippecanoe River at Buffalo (0.16 mg/l). TP was lowest at Keens Creek (0.05 mg/l), Timmons Creek (0.05 mg/l), Williams Ditch (0.08 mg/l), and Big Monon Ditch (0.09 mg/l). TKN was highest at McKillip Ditch (1.7 mg/l), Big Monon Creek (1.7 mg/l), Timmons Ditch (1.4 mg/l), and Carnahan Ditch (1.4 mg/l). The lowest TKN concentrations were observed at Big Monon Ditch (0.3 mg/l), Keens Creek (0.6 mg/l), and Williams Ditch (0.7 mg/l).

1986. A limnological survey of Lake Shafer at Norway Dam was conducted on August 14, 1986 by IDEM personnel. In-situ measurements were made of Secchi depth, percent light transmission, temperature, pH, DO, and conductivity. In addition, plankton tows were conducted between a depth of five feet and the surface and between depths of ten and five feet. The water column was not strongly stratified, as evidenced by a 0.6 degree difference between the surface and bottom waters. Dissolved oxygen was near saturation at the surface (11.1 mg/l), and moderately low at the bottom (2.4 mg/l). These values indicate generally healthy conditions in the water column.

Water samples were collected at the surface, 5, 10, and 17 feet (1 foot off the bottom). Samples were analyzed for NH_3, iron (Fe), nitrate/nitrite (NO_2/NO_3), TP, and TKN. Nitrogen components were generally consistent throughout the water column (0.1 mg/l NH3, 0.5 mg/l NO_2/NO_3, and 1.0 mg/l TKN), with slight increases in the bottom samples (0.3 mg/l NH_3, 0.5 mg/l NO_2/NO_3, and 1.4 mg/l TKN). Total phosphorus increased from 0.06 mg/l at the surface to 0.11 mg/l at 17 feet. These values are characteristic of moderately eutrophic lakes where phosphorus is the limiting macronutrient (N:P ratios of 16.7:1 to 12.7:1).

2.2.5 IDEM Stream Water Quality Data

Historically, IDEM has collected water quality data from a series of stations along the Tippecanoe River:

- TR-6 at the SR 18 Bridge, 5 miles west of Delphi; 1957-70, 1976-present
- TR-48 near Ora; 1957-72
- TR-53 at the US 35 bridge near Winamac; 1971-72
- TR-107 at Rochester; 1986-present
- TR-145 at the US 30 bridge near Warsaw; 1971-72

Data collected at these stations are variable, but generally include flow, chlorides, alkalinity, hardness, turbidity, NO_3, pH, conductance, total suspended solids (TSS), volatile suspended solids (VSS), TP, biochemical oxygen demand (BOD), fecal coliforms, temperature, and DO.

Of these stations, TR-6 is the only one that has a long period of record, and it is located downstream of Lake Shafer.

2.2.6 Erosion Potential Summaries

Three erosion potential analyses have been conducted and are available for counties in the Lake Shafer watershed.

IDNR Watershed Analysis. This analysis was conducted in 1981 or 1982 using soil association characteristics to develop a distribution of water erosion index values for the Lake Shafer watershed. The data are readily available from SCS, but the analysis was never published. The results indicate that approximately 70 percent of the watershed is composed of soils that have a slight to negligible potential for water erosion. The remaining 30 percent of the basin is characterized by a slight to moderate erosion potential.

IDNR Water Resource Report. IDNR published "The Indiana Water Resource--Availability, Uses, and Needs," (C.G. Douglas, 1980). The report presents regional analyses of various aspects of water resources, including soil erosion potential. A map is included showing the areas of high erosion potential within the Tippecanoe River watershed. This map indicates that approximately 432,600 acres, or 35 percent of the watershed has a high potential for sheet and rill erosion. The highest potential is in the counties in the upper portion of the watershed (Figure 3).

Northeast and Northwest-Central Indiana Erosion Studies. These studies were conducted by SCS and IDNR. The results are presented in individual county reports and overall study reports. Maps are presented showing areas where sheet, rill, and gully erosion are the predominant problem (Figure 4). Analyses of the data indicate that 365,387 acres, or 32.9 percent of the counties covered in these studies and within the Lake Shafer watershed are dominated by these forms of water erosion.

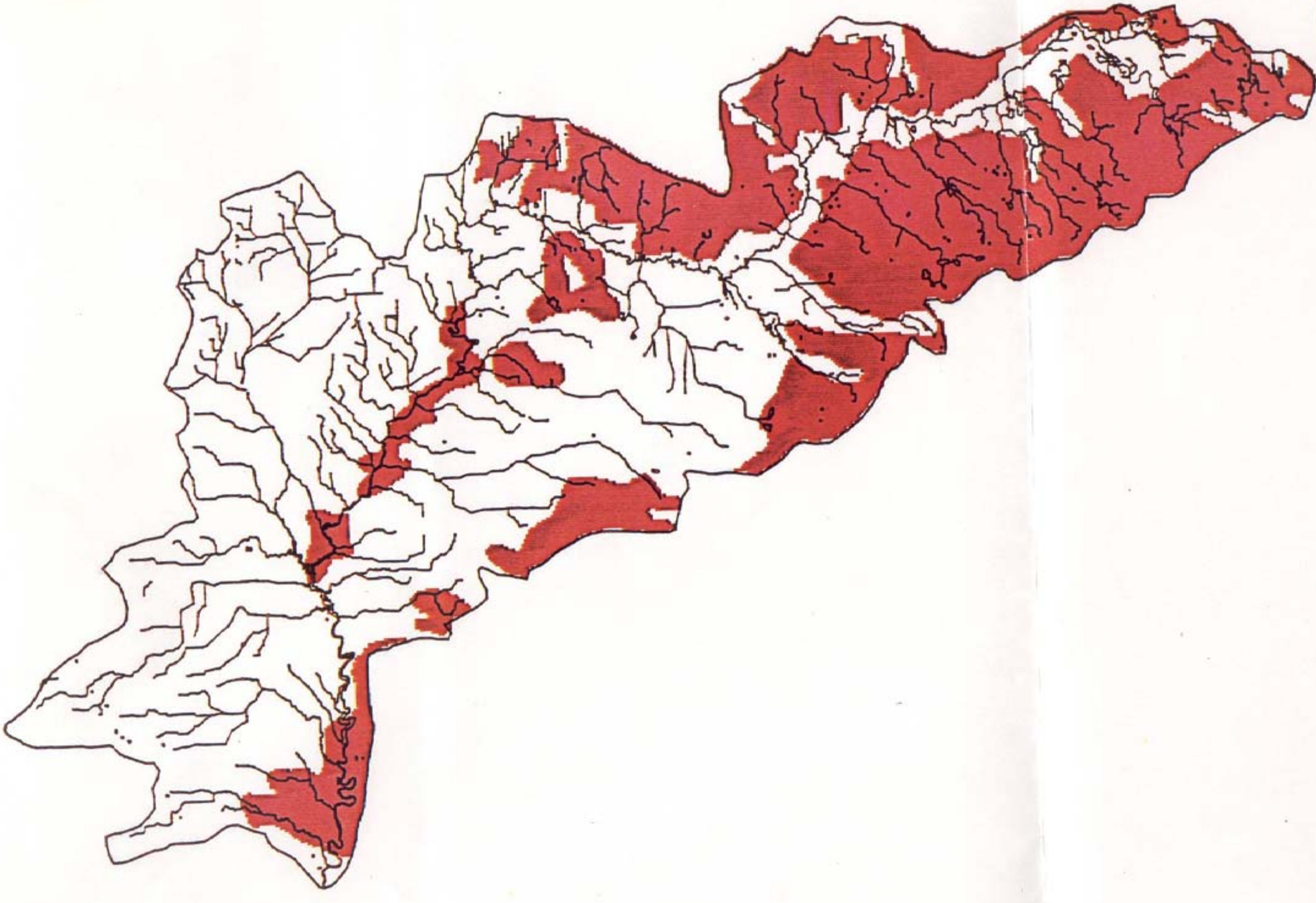


Figure 3. Areas Subject to Moderate and Severe Soil Erosion as reported in "The Indiana Water Resource." (IDNR)

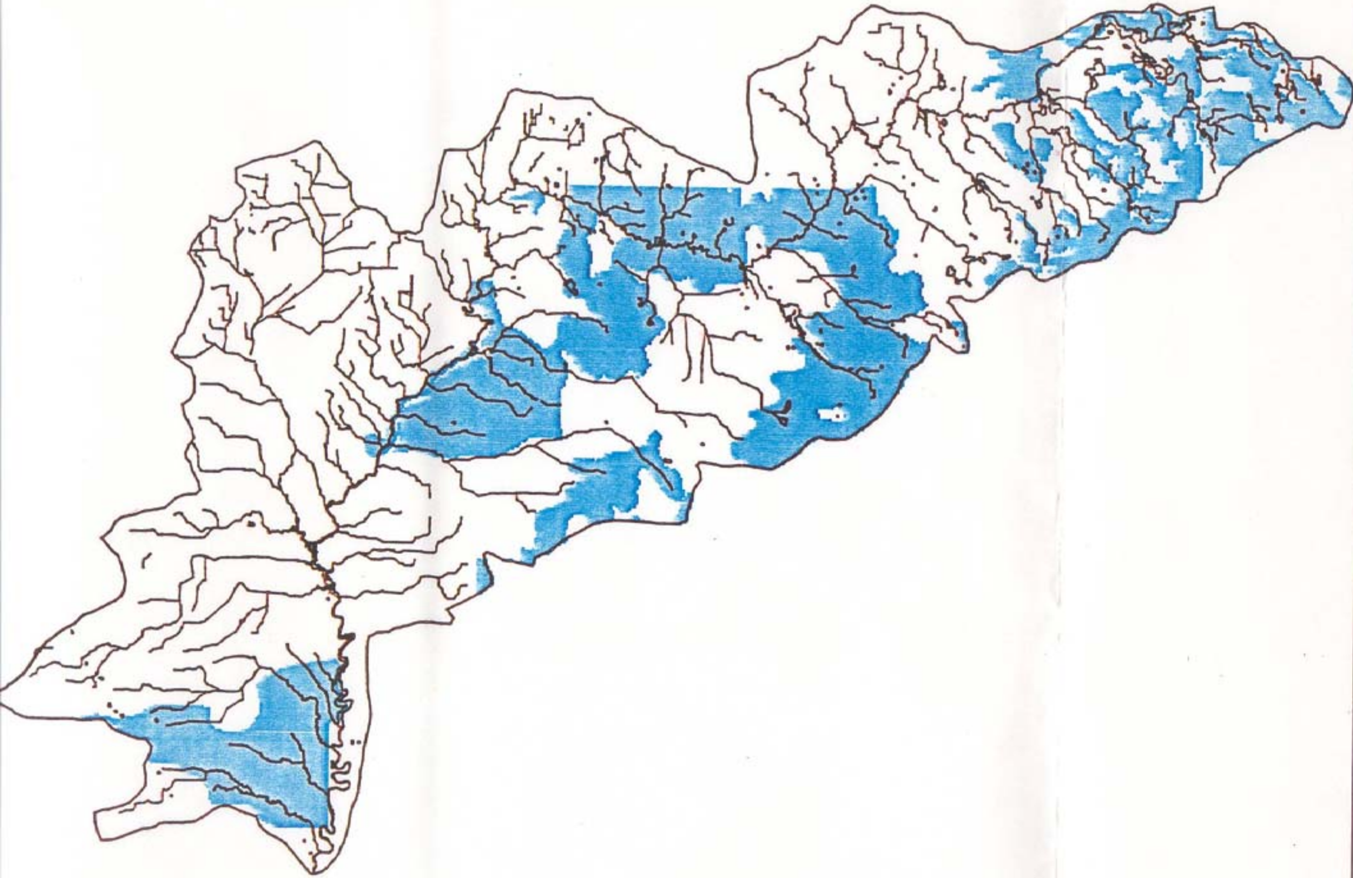


Figure 4. Major Erosion Problem Areas Where Sheet, Rill, and Gully Erosion Predominate as Reported in the NE and NW-Central Indiana Erosion Studies.

SECTION 3. WATERSHED CHARACTERIZATION

This section presents a summary from the literature of watershed characteristics based on the information collected.

3.1 WATER FEATURES

The headwater of the Tippecanoe River is on the northern edge of Whitley County in Little Crooked Lake. Simons (1985) gives a detailed description of the path of the Tippecanoe River from its origin to its confluence with the Wabash River below Lake Freeman. The river basin consists of 563 miles of streams, 509 miles of ditches, and 950 miles of intermittent streams draining 1730 square miles of land (Figure 5). There are also 206 lakes and ponds within the basin.

Uses of the waters include hydroelectric power generation at Norway and Oakdale dams, swimming, fishing, boating, and water skiing. Estimates of the value of the lake to the state in tax revenues alone are in the neighborhood of $5 million.

3.2 LAND USE

Land use data are available in the form of SCS workload analyses for the 11 counties that fall within the Tippecanoe River basin. Table 3 presents a summary of these data. The watershed is predominantly agricultural with relatively little land in forest or urban centers.

A wide range of point sources of pollution exist within the watershed. There are a total of 63 National Pollution Discharge Elimination System (NPDES) permits from the Lake Shafer watershed on file with the IDEM. These permits cover activities as diverse as municipal waste treatment plants and metal plating operations.

Feedlots with at least 600 hogs, 300 cattle, or 30,000 poultry are permitted by IDEM. Permit records show that 92 feedlot permits for facilities within the watershed are currently on file with IDEM.

TABLE 3. SUMMARY OF SCS LAND USE DATA.

County	Total Area	Cropland	Pasture	Forest	Other
Cass	265,600	196,134	17,082	18,981	33,403
Kosciusco	355,200	221,000	31,000	29,000	74,200
Jasper	360,000	277,000	32,000	23,000	28,000
White	318,000	269,000	18,000	12,000	19,000
Fulton	236,800	188,000	14,000	15,000	19,800
Starke	200,300	139,000	2,500	23,000	35,600
Marshall	287,360	201,000	16,900	27,500	42,077
Pulaski	277,000	211,000	12,000	29,000	24,800
Miami	243,200	171,694	29,916	18,119	23,471
Noble	262,400	185,462	21,268	25,524	30,146
Whitley	215,000	147,290	27,058	20,102	20,550
Totals	3,020,860	2,206,580	221,724	241,226	351,047
% of Total Area		73.0%	7.3%	8.0%	11.6%

Permitted mining activities within the watershed include crushed stone (two locations), sand and gravel (four sites), marl (six locations), and peat (three sites).

3.3 SOIL EROSION POTENTIAL

As discussed in Section 2.2.7, there are several erosion potential summaries available for lands within the watershed. Figure 6 presents a summary of the mapped studies. The data show that most of the soils potentially subject to excessive water erosion are in the upper regions of the watershed.

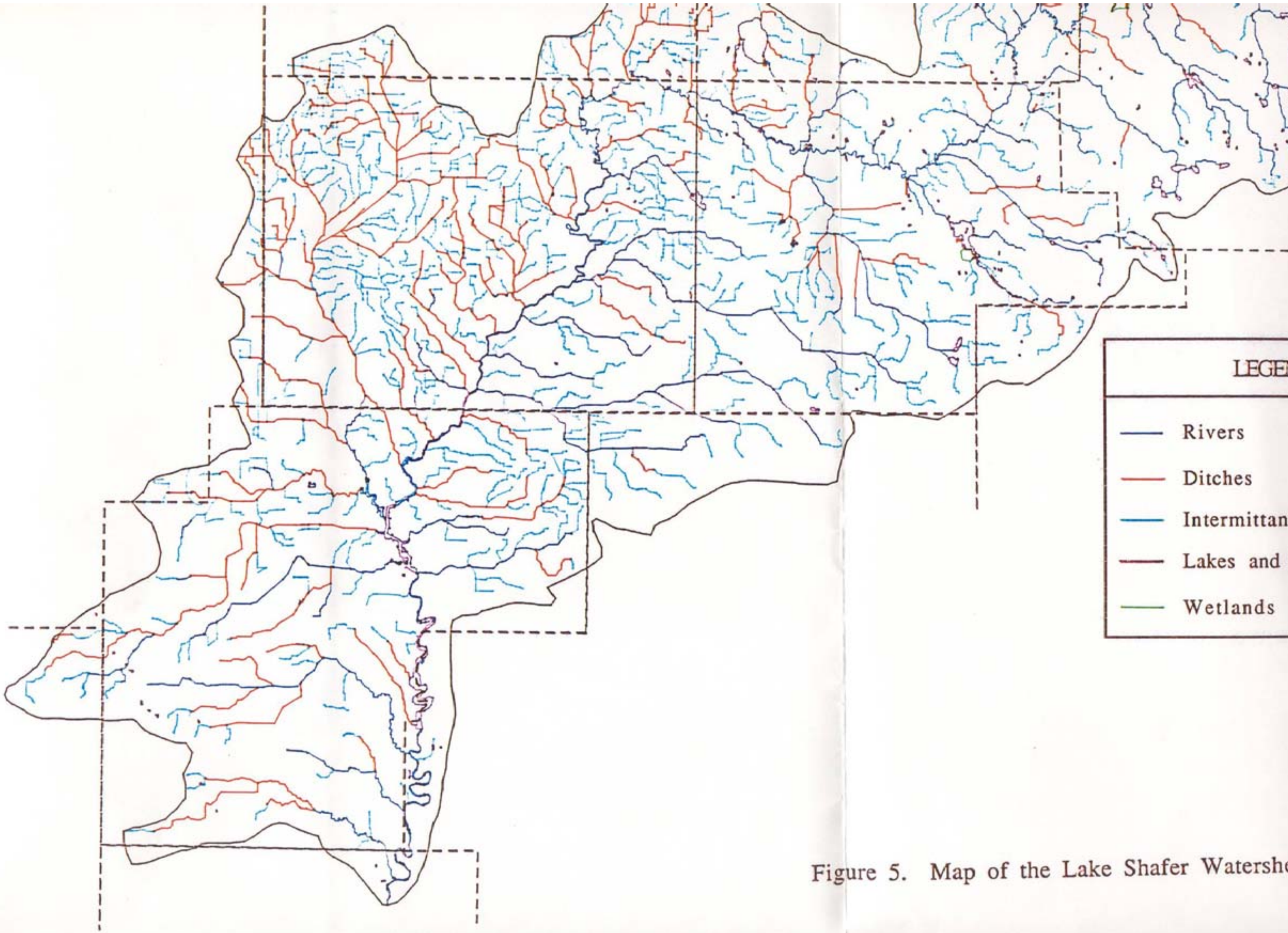
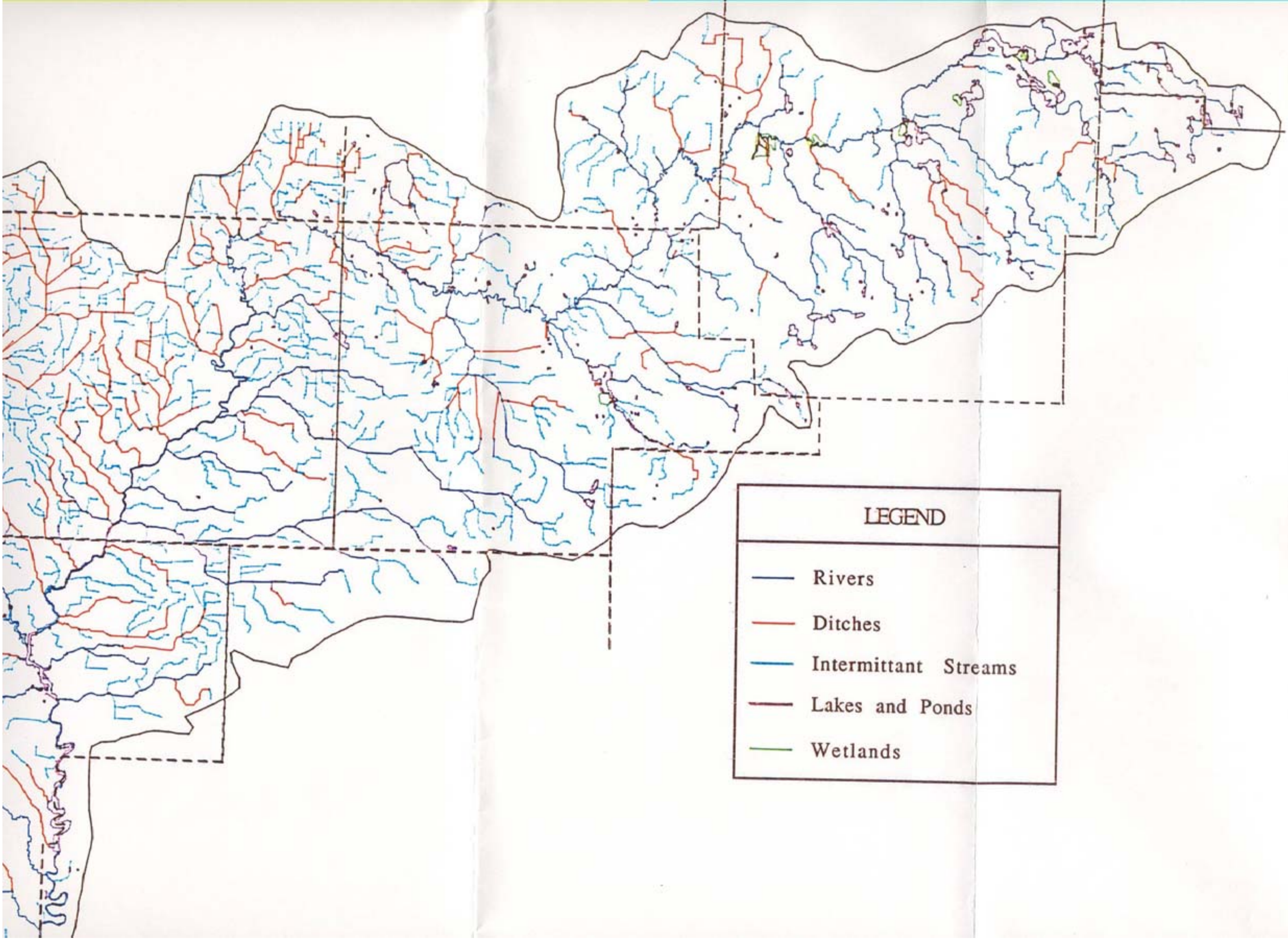


Figure 5. Map of the Lake Shafer Watershe


LEGEND
Rivers
Ditches
Intermittant Streams
Lakes and Ponds
Wetlands

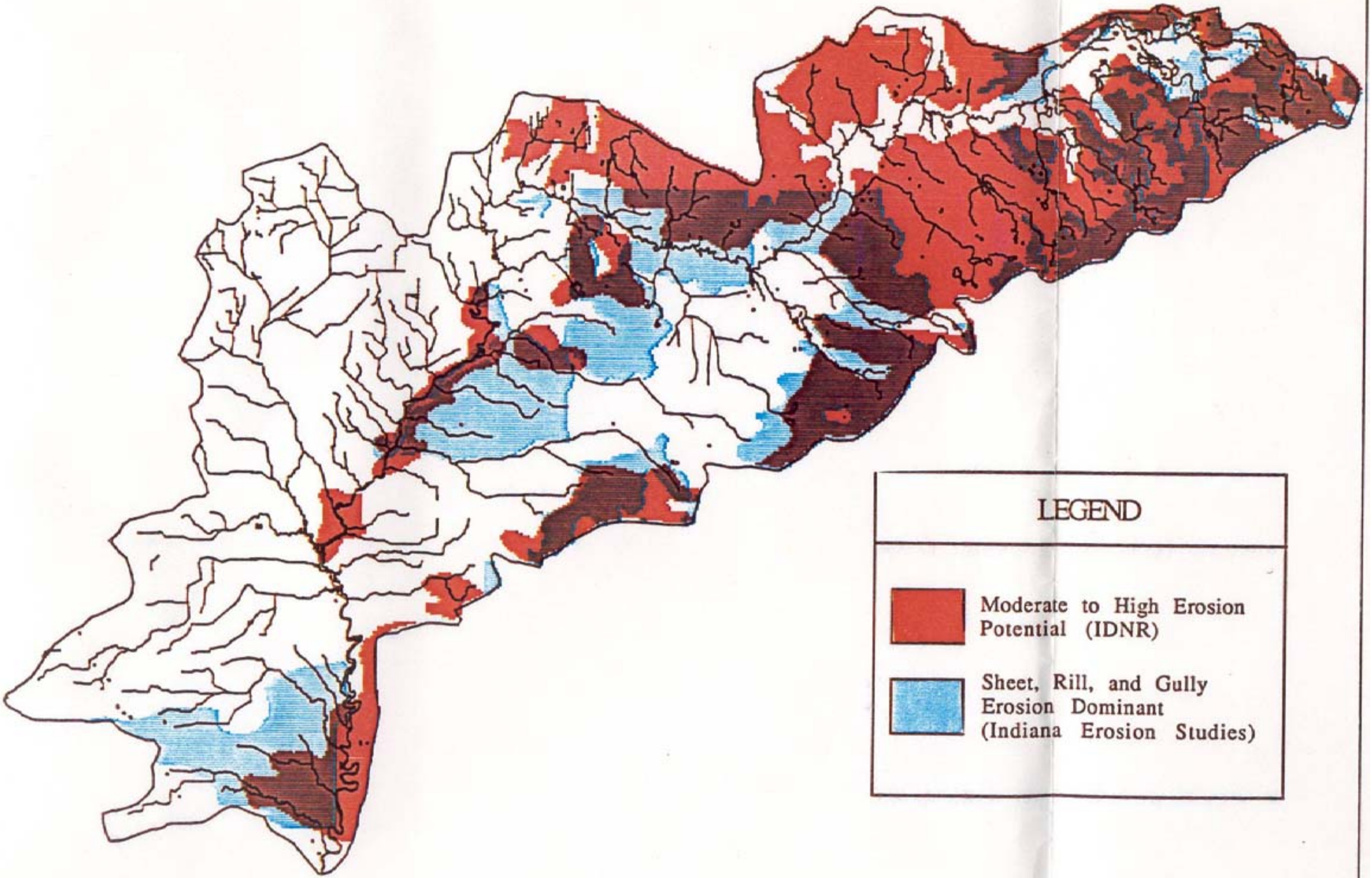


Figure 6. Comparison of IDNR and Indiana Erosion Studies Data.

SECTION 4. DISCUSSION

Sedimentation is a natural and inevitable process in all reservoirs and lakes. Man-made environmental features are inherently less stable and shorter-lived than similar natural features. Reservoirs tend to have higher sediment accumulation rates than natural lakes. This may be attributed to the fact that natural lakes are formed and survive where conditions favor their existence. In contrast, the placement of reservoirs is typically driven by topography, availability of land, and demographics.

The rate at which lakes and reservoirs fill with sediment is a function of soil erosion, hydrology, and trophic state (i.e., productivity), among other things. The management of lakes and reservoirs requires an understanding of the dominant forces affecting the water body, as well as a recognition of the areas of control in which management is feasible.

4.1 CURRENT STATUS OF LAKE SHAFER

The accumulation of sediment is definitely a problem in Lake Shafer. The historical data clearly indicate that reservoir capacity is being lost and recreational uses are being impaired. Moreover, costly damage is being sustained by shoreline structures and properties as a result of the increasing occurrence and magnitude of ice jams during the spring thaw. The problem appears to be moving steadily downstream towards Norway Dam. The key issues remaining concern the identification of the mechanism responsible for the increased accumulation of sediments in the lake over time, the control options capable of correcting the causes, and the measures that are available to mitigate the existing problems in the lake.

4.2 EROSION IN THE WATERSHED

The USGS stream sediment data (Section 2.2.3) provide evidence that sediment loading from the upper one-half of the watershed to the

Tippecanoe River has remained relatively constant over time. An average sediment discharge of 0.05 tons/ac-yr. was estimated for this portion of the watershed in the period between 1968 and 1979. This value is consistent with the observed sediment accumulation rates in the lake (i.e., 0.06 - 0.11 tons/ac-yr.). Trend analysis showed no indication of increasing loads during this period. It should be noted that the area represented in the USGS study has the greatest proportion of potentially erodible soils within the Tippecanoe River watershed.

There were several observations in the historical sediment surveys suggesting that Big Monon Dredge Ditch was a major source of sediment loading to Lake Shafer. The Big Monon Dredge Watershed Study (Section 2.2.2) concluded that erosion within this sub-basin may be expected at a rate of 1.05 tons/ac-yr. This is significantly lower than the "T" value of 5 tons/ac-yr., indicating that, for the most part, the land is being effectively managed. However, this sediment export rate is an order of magnitude greater than the rate reported by the USGS for the upper portion of the Tippecanoe River basin.

An estimate of the total annual sediment contribution from the Big Monon Dredge Ditch sub-basin may be obtained by multiplying the estimated effective sediment yield of 0.54 tons/ac-yr by the total acreage of the sub-basin (i.e., 117,760 acres). The resulting estimate of 63,590 tons/yr is nearly half of the estimated annual sediment accumulation in Lake Shafer (i.e., 121,933 tons). This estimate substantiates the conclusions of the 1954 and 1983 sediment surveys that Big Monon Dredge Ditch is a major source of sediment to Lake Shafer. This information indicates that excessive soil erosion (relative to "T") in the watershed is not at the heart of the problems in Lake Shafer. However, erosion rates in specific areas within the watershed may be excessive and amenable to reduction through land treatment practices. Reduction of such localized erosion can only improve the situation for sediment loading to Lake Shafer.

4.3 SEDIMENT ACCUMULATION RATES

The rate of sediment accumulation in Lake Shafer is an important key in understanding the magnitude of the problem and identifying potential causes. The 1986 IDNR Sediment Survey Report analyzed changes in capacity as a function of time and concluded that sedimentation had increased during the period between 1960 and 1986 (Figure 2). This conclusion was based on four capacity estimates and the assumption that changes in capacity over time will be linear. Figure 7 presents a plot of data from the four surveys in terms of annual sediment accumulation in tons per acre of watershed (Table 2). The average sedimentation rate increased 25 percent from 0.06 to 0.08 tons/ac-yr. over the 20 years between the 1940 survey and 1960. In the 26 years between 1960 and 1986 the mean rate increased 27 percent, from 0.08 to 0.11 tons/ac-yr. Although the data are insufficient to conduct a rigorous error analysis, it is doubtful that there is a practical difference between these two rates of change. It appears that there has been a relatively steady increase, or acceleration, in the rate of sediment accumulation in Lake Shafer since its creation.

4.4 SEDIMENT DELIVERY MECHANISMS

Most of Lake Shafer used to be substantially deeper than it is today. The evidence shows that sediment loading in the Tippecanoe River is within the normally acceptable range, and in fact is on the lower end of the range observed by the USGS for rivers in the state. Moreover, the sediment discharge observed for the Tippecanoe River is consistent in magnitude with the rates of sediment accumulation observed in the lake, although these rates appear to be increasing over time. The question remains: "What mechanism has caused the critical conditions that currently exist in the lake?"

A key to the solution is provided by observations reported in the 1954 and 1983 sediment surveys (Section 2.2.1). There were substantial increases in sediment depth noted at the mouths of Big Monon Creek and Hoagland Ditch. Moreover, in the both of these reports, Big Monon Dredge

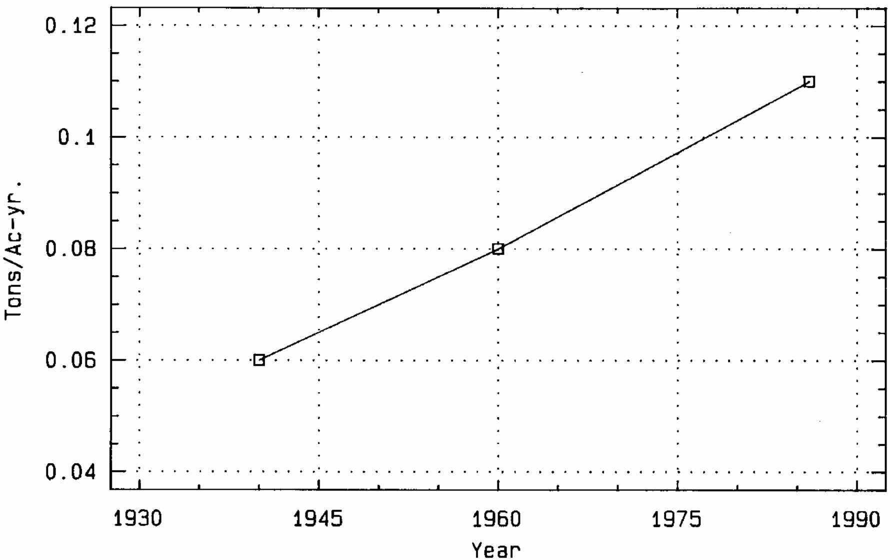


Figure 7. Sediment Accumulation Rates.

Ditch was implicated as a significant source of sediments to the lake. In the 1983 report, J. Strange concluded that the sediment trapping capacity of the upper reaches of the Tippecanoe River system has been exhausted. The current investigation has come to the same conclusion.

Apparent sedimentation rates have increased in Lake Shafer as the delivery rate of suspended sediment from the Tippecanoe River has increased. This increase may be attributed to a progressive filling of natural sediment traps in the drainage basin. As the upstream traps become filled to capacity, the material they would have intercepted is transported downstream to the next trapping area. Downstream sediment traps are filled at an accelerated rate as loading rates increase. The net effect is an increasing rate of sediment delivery to, and capacity loss in, Lake Shafer.

There are a number of potential explanations for the discrepancy between an apparent increase in sediment delivered to Lake Shafer and the USGS stream sediment study that reported no statistically significant trend in increasing sediment discharge from the Tippecanoe River basin. Increased sediment delivery may have been in the form of bedload discharge that would not be included in sediment discharge samples. This is a plausible concept in that the material that would normally be deposited in upstream sediment traps would be the larger and heavier sediment fractions. As sediment trapping capacity diminished, these larger fractions would be likely to be transported downstream as part of the bedload. A second possibility is that the lower portions of the river basin have experienced an increase in sediment discharge. There are no data available to either support or refute these possibilities.

4.5 CONCEPTUAL MODEL

The 1986 IDNR sediment survey (Section 2.2.1) reported that there there had been an increase in the rate of sediment accumulation during the period of 1960 to 1986 (Figure 2). The implication was that something had changed in the watershed to increase erosion rates. The hypothesis of the current investigation is supported by the reported observation, but not the implied conclusion. Sediment yield rates have apparently remained relatively constant, but sediment trapping capabilities have changed in the watershed.

A simple conceptual river system sedimentation model (Figure 8) may be used to illustrate the occurrence of increasing sediment accumulation rates in a reservoir under conditions of constant erosion in the watershed. This model is intended for illustrative purposes and not necessarily to represent the actual rates or removal mechanisms that may exist in the Lake Shafer system. The modeled system consists of two sub-basins with sediment traps and a reservoir. Sediment trapping rate is described by the following simple relationship:

$$dS_i/dt = R_i \ (1-c_i/C_i) \ S_i \ t^{-1}$$

where
S_i = Mass of sediment transported from sub-basin i (M)
t = Unit time step (T)
R_i = Maximum removal efficiency of trap i (dimensionless)
c_i = Mass of accumulated sediment in trap i (M)
C_i = Maximum capacity of trap or reservoir i (M)

The effective trapping efficiency decreases as the trap or reservoir accumulates sediment. Efficiency approaches zero as the trap approaches its ultimate capacity. Table 4 presents a summary of the loading rates, removal efficiencies, and trap capacities used for this model. These values are not based on any reported data. Rates are with respect to a unit time step.

The model simulation was run over 100 time steps. Figure 9 presents a plot of sediment accumulation for the two traps and remaining water capacity for the reservoir in the model system. The figure clearly shows how reservoir capacity declines at an increasing rate as the upstream sediment traps initially begin to fill. This increasing trend in rate of capacity lost changes when the upstream traps approach 50 percent capacity. Although the development of a realistic model of the Lake Shafer system is beyond the scope of this investigation, this illustration provides an insight into the probable mechanism behind the observed rate of decline in capacity in the system.

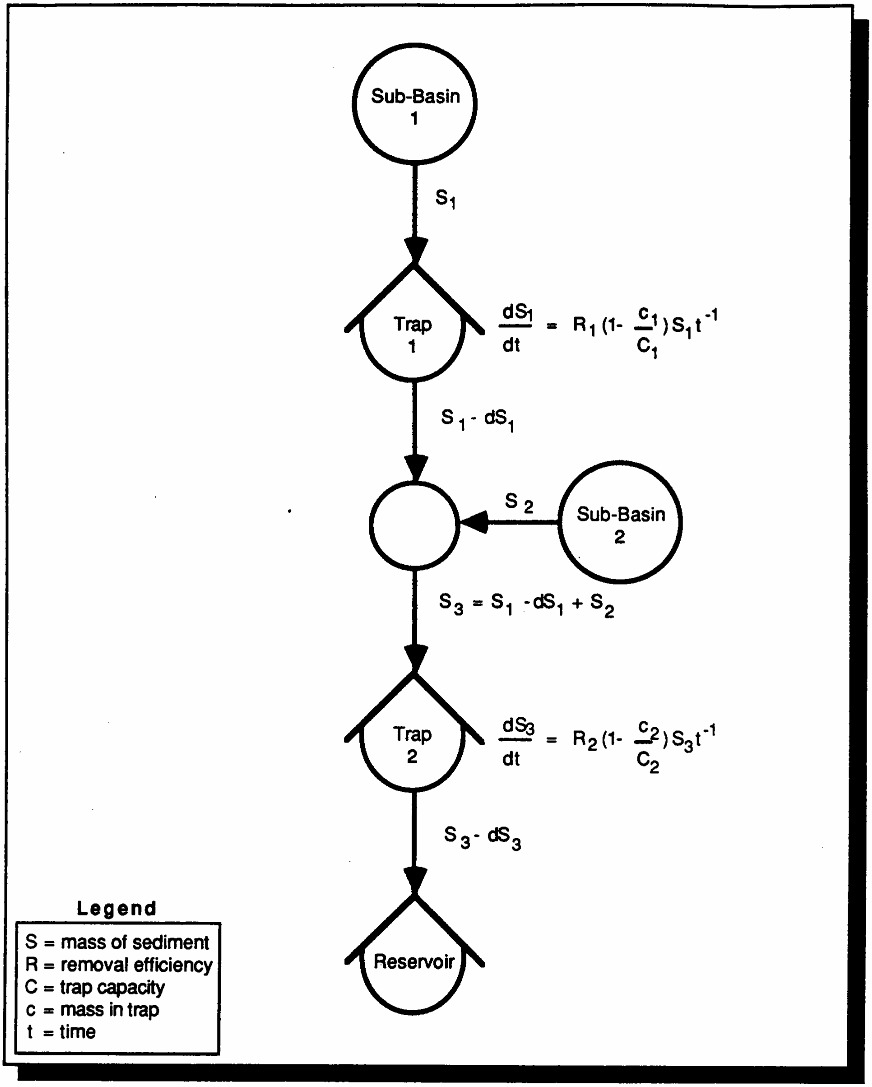


Figure 8. Conceptual River Basin Sediment Transport Model.

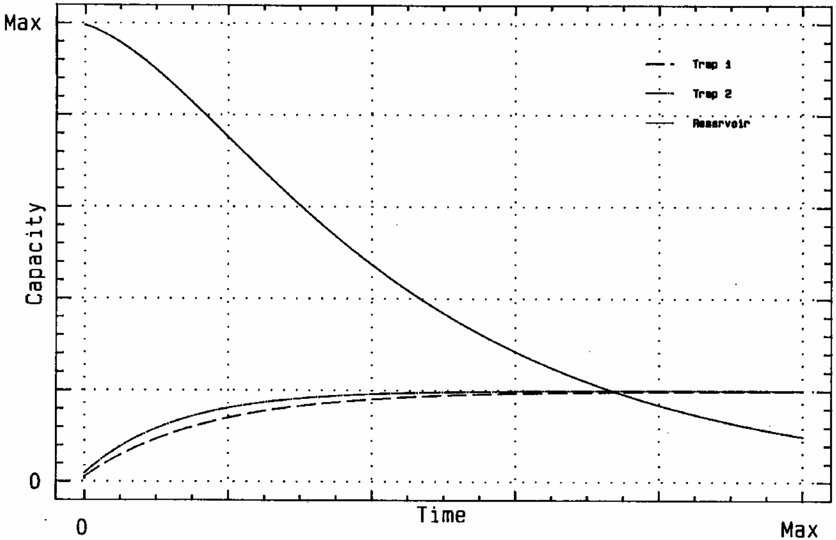


Figure 9. River Basin Simulation

TABLE 4. MODEL COEFFICIENTS AND INPUT VALUES.

Process	Value Used
Sediment Removal Efficiency (R)	
Trap 1	0.75
Trap 2	0.75
Reservoir	0.75
Sediment Capacity (C)	
Trap 1	100
Trap 2	100
Reservoir	500
Sediment Load (S)	
Basin 1	7.5
Basin 2	10

4.6 MANAGEMENT STRATEGY

Both the causes and the symptoms of the sediment accumulation problem in Lake Shafer must be addressed if an effective restoration is to be accomplished. The causes of sedimentation appear to be relatively low rates of sediment discharge from the watershed and a decline in the effectiveness of natural sediment traps in the drainage basin. The management approach should focus on two strategies that will minimize sediment loading to the lake: minimization of erosion and maximization of sediment trapping capacity.

The practical minimization of erosion from the watershed should be pursued through identification of localized areas where erosion is a significant problem. By keeping the soils in place through the application of appropriate treatments to these "hot-spots," river and lake sedimentation problems will be reduced.

The second component of the recommended strategy is the identification of naturally occurring traps, as well as investigation of the potential for constructing new, and possibly more effective sediment control facilities. These efforts will promote the retention of eroded soils within the watershed, and reduce sediment loading to the lake. It should be noted that the restoration and enhancement of sediment trapping capacity has long-term maintenance requirements (e.g., periodic sediment removal) which make it a generally less desirable management strategy than the reduction of soil loss from the land.

The symptoms of sediment accumulation in Lake Shafer have reached unacceptable proportions and must be addressed if the value of the resource is to be restored. Management efforts should focus on the best alternatives for sediment removal and estimation of the amount of sediment to be removed.

SECTION 5. RESTORATION ALTERNATIVES

This section discusses the technologies and strategies that are available to address the problems of sediment transport in the Tippecanoe River system and sediment accumulation in Lake Shafer. Emphasis is placed on the development of a sediment removal and control strategy, identification of appropriate technological solutions, and a discussion of the advantages and disadvantages associated with each alternative. This emphasis is not intended to minimize the importance of controlling soil erosion at the source through effective land treatment.

5.1 RENOVATION/CONSTRUCTION OF SEDIMENT TRAPS

Effective mitigation of sediment discharges into Lake Shafer will require the identification and renovation of sediment traps within the watershed. Sediment traps typically consist of basins or wide areas in streams where relatively quiescent conditions allow suspended particulate matter to settle out of the water column.

5.1.1 Renovation of Natural Sediment Traps

Several naturally occurring sediment traps have been identified in the historical surveys of the lake. These include the mouths of Big Monon Creek and Hoagland Ditch where significant accumulations of sediment have been documented. There are probably other basins upstream that have effectively served as sediment traps.

The first step in restoring the natural sediment trapping capabilities within the watershed should be a comprehensive inventory of areas that have historically served as sediment trapping basins. This effort will require traveling the length of the Tippecanoe River and its major tributaries to identify and document these sites. The reviewed data indicate that most of these sites will be in the lower portion of the watershed. Interviews with local residents will be helpful in identifying those areas of the river system that have shown substantial sediment accumulation since the 1920s.

Once the natural sediment traps have been identified, they should be ranked in order of capacity, probable effectiveness, and ease of renovation to identify those sites that will provide the maximum protection for the lake at the most reasonable cost. Estimates should be computed of probable sediment accumulation rates to predict maintenance requirements. The long-term effectiveness of the restoration effort will depend on a well planned and executed maintenance program. A watershed sediment transport model will be required to construct these estimates at a reasonable level of confidence.

5.1.2 Constructed Sediment Traps

It may be possible to provide additional protection for Lake Shafer by constructing artificial sediment traps to supplement naturally occurring traps in the watershed. The advantages of constructed sediment traps include the ability to select sites and configurations that provide for maximum removal efficiency and ease of maintenance. For example, a constructed basin site may be located such that periodic sediment removal is facilitated by proximity to access roads and disposal areas. Similarly, modification of existing natural traps may provide enhanced sediment removal capabilities.

One potential site for a constructed sedimentation basin exists at the mouth of Big Monon Dredge Ditch. This site is particularly attractive since the ditch has been identified as being a significant source of sediment loading in the basin. The ditch widens into a wetland area just upstream of the Highway 39 bridge. The berm of the roadway and the existing land elevation form a shallow basin. Enlargement and deepening of this basin may provide an effective means of removing sediment from the ditch discharge before it enters the Tippecanoe River.

In conjunction with the survey of existing sediment basins, a survey of potential sites for constructed sediment basins should be conducted. Site priorities should be established based on sediment contribution at the site relative to the total discharge to Lake Shafer, removal potential of the proposed basin, and ease of maintenance.

5.2 IN-LAKE SEDIMENT REMOVAL

An effective restoration of Lake Shafer will require removal of some portion of the accumulated sediments from the lake. It will be necessary to remove enough material to support current uses of the resource and absorb additional sediment deposition that will occur in the future. A minimum depth of five feet was recommended by the 1986 IDNR sediment survey to prevent the formation of ice jams. This depth should provide for adequate access and recreational use, as well as protection for shoreline structures. Estimation of the amount of additional sediment that should be removed (above and beyond that required to provide adequate depth) will require modeling sediment discharge from the watershed. The model should include the expected effects of all renovated and newly constructed sediment traps that are proposed. Cost projections will be required to determine the most cost effective maintenance interval.

Although sediment traps in the watershed will reduce sediment loading to the lake, in-lake deposition will not be eliminated. Under ideal conditions this deposition will be at relatively low rates, but the lake will lose capacity over the years. As an example, if lake capacity were increased to 14,000 ac-ft. through sediment removal, and sediment accumulation were reduced to the historically low level of 0.06 tons/ac-yr. through restoration/construction of sediment traps, then it is estimated that the lake would return to its presently unacceptable condition within 74 years. A realistic lake management plan must consider periodic sediment removal from the lake basin.

5.3 SEDIMENT REMOVAL TECHNIQUES

The technologies available for removing sediment may be applicable to either Lake Shafer or to the renovation/construction of sediment traps. Sediment removal techniques may be classified as either wet or dry: dry techniques require drawing the lake down or otherwise exposing and partially drying the sediments; wet techniques are conducted in-situ with the sediments submerged.

5.3.1 Dry Techniques

All dry sediment removal techniques are similar in that they involve draining the water body sufficiently to allow heavy machinery to be used in physically removing the exposed sediment. Earth moving equipment such as bulldozers, draglines, backhoes, and dump trucks are typically used. The major advantage of this approach is that it allows the sediments to partially dewater and consolidate. Thus, the removed material has a relatively high solids content and can be efficiently moved over roads by truck. In addition, there is excellent control over the quantity and location of sediments removed and relatively little sediment resuspension occurs.

The major disadvantages of dry sediment removal include cost and logistical limitations. Because the material is trucked over roads, the cost per cubic yard removed tends to be higher than hydraulic dredging. Getting the heavy machinery in and out of the work site is often a problem in highly developed shoreline areas. The construction of plank roads is often required for moving heavy machinery over soft lake sediments. In some cases, machinery access to sediment deposits may be impossible. The transporting process typically results in a lot of sand and mud being deposited in the roads between the shoreline and the disposal area. This can present a serious public relations problem where a large volume of sediment is being removed over a period of many months.

A prolonged drawdown of Lake Shafer may or may not present a problem. The surrounding communities would probably be supportive of a drawdown in association with the restoration effort. All dredging activities would have to be scheduled during spring and fall months to avoid any possible deleterious impact on tourism and lake use during the peak summer months. Obtaining the cooperation of the North Indiana Public Service Company (NIPSCO) in keeping the lake at a low elevation for several months would probably present the greatest potential obstacle. Norway Dam would be effectively shut down during the entire operation. This is an area of discussion that should be pursued with

NIPSCO officials. Finally, a prolonged drawdown of the lake may have deleterious effects on aquatic habitat and recreational fishing resources that should be investigated during the restoration planning process.

5.3.2 Wet Techniques

Wet sediment removal techniques involve either scooping up bottom material in buckets that are emptied into a barge or truck for transport to a disposal area, or suspending the material in a slurry and transporting it through a pipe.

Bucket dredges typically consist of a dragline or a backhoe operated from a barge platform. A second barge is used to hold the dredged material (spoil). When this barge is full it is moved to a shore site where the spoil is transferred to a truck for disposal. The advantages of bucket dredges include a relatively high solids content in the spoil and a high degree of maneuverability in confined areas. The disadvantages include turbidity in the lake from resuspension of the bottom sediments and relatively low rates of removal.

Hydraulic dredges are the most common machines used in large wet dredging operations. The dredge consists of a cutter head mounted on the end of a suction pipe suspended from a barge. As the cutter dislodges the sediments, the loosened material is sucked into the pipe in the form of a slurry. The barge houses the drive machinery for the cutter head and pumps. The slurry pipe typically extends from the dredge barge to the shoreline, and from there to the disposal area. Because the dredged material is suspended in a slurry, a settling basin is necessary as an integral part of the disposal site. The basin is designed based on the physical properties of the sediments being dredged. Once the sediment has settled out of suspension, the remaining, or "return" water is either returned to the lake or discharged to some other receiving water.

The advantages of hydraulic dredging include relatively high removal rates, high cost efficiencies, and minimum impact on the shoreline. The disadvantages include generally high levels of turbidity in the lake from the cutter head and return water from the settling basin, the requirement for a suitably large disposal area, and the need for a suitable pipeline route from the lake to the disposal area.

5.4 DISPOSAL ISSUES

Regardless of the technique used to remove the sediment, a suitable area will be required for its disposal. The disposal area must be large enough to receive the total volume of sediments targeted for removal, as well as water that will be entrained in the dredged material. Moreover, the disposal area must be close enough to the lake to allow efficient transport over an acceptable route. In the case of trucked material, the roads must be suitable for sustained heavy traffic. Hydraulic dredging requires that a pipeline route be available to efficiently pump the slurry. Routing should avoid elevation increases and take advantage of natural slopes to promote flow from the lake to the disposal site. It is preferable to discharge the return water from the settling basin to the originating lake to limit the environmental disruption to the original body of water.

Stream and lake sediments may contain hazardous concentrations of toxic materials, such as pesticides and heavy metals. Adequate testing must be conducted on the lake sediments early in the planning stages to ensure that the dredged material will not present a hazardous waste issue. Dredging will be effectively precluded as a restoration alternative if test samples fail to pass standard extraction procedure (EP) toxicity tests (Carranza and Walsh, 1985).

Although rare, it may be possible to dispose of the dredged sediments through a reuse program. Stout and Barcelona (1983) reported on a demonstration project that was successful in applying dredged lake sediments from a mid-western lake to agricultural lands as a soil amendment. Special application techniques were used to minimize the subsequent loss of nutrients and sediments from the treated fields. This option should be considered in conducting a dredging feasibility study for Lake Shafer.

5.5 PERMITTING ISSUES

Any dredging project will require a wide range of permits from local, state, and Federal agencies. As an example, a sediment removal project on Lake Springfield, a 3,700 acre lake in Illinois (Buckler, et al., 1988) required the following permits and certifications:

- Dredging Permit (Army Corps of Engineers)
- Exemption from the Rivers and Harbors Act of 1899 (Army Corps of Engineers)
- Construction and Operating Permit (Illinois Environmental Protection Agency)
- Dam Safety Permit for the disposal site berm (Illinois Department of Transportation)
- Compliance with the National Historic Preservation Act
- Compliance with city and county zoning ordinances

5.6 COST ESTIMATES

Dredging is one of the most costly restoration strategies for lakes and reservoirs (Carranza and Walsh, 1985). Costs vary substantially with site specific conditions, limitations, and circumstances. Reported costs in the literature range from $0.33 to $13.08 per cubic yard of sediment removed (Peterson, 1986). Typical costs are in the range of $2.00 to $3.00 per cubic yard.

It is possible to get an order of magnitude estimate of the cost of removing sediment from Lake Shafer. It is assumed that 3,500 ac-ft. (5,647,000 cubic yards) of sediment will be removed to return the lake to its pre-1940 capacity of 14,000 ac-ft. The unit cost of removal is assumed to be be $2.25 per cubic yard. This cost is based on the assumption that a local contractor will be able to perform the work at the lower end of the typical range of costs. All permitting, disposal, and environmental costs are included in this estimated unit cost. The resulting preliminary cost estimate for dredging Lake Shafer and the mouths of Big Monon Creek and Hoagland Ditch is $12,700,000. This estimate does not include sediment removal from sediment traps in the watershed, because the required volume of sediment is unknown at this time. It must be emphasized that this is a preliminary estimate based solely on reported costs in the literature. There are many site specific considerations that will affect the actual cost of performing this work.

SECTION 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The observed sediment accumulation in Lake Shafer is the result of a natural process that has not been accelerated by increasing or excessive erosion in the Tippecanoe River watershed. The reported sediment discharge rates for the watershed appear to be temporally stable and are substantially lower than rates that would be expected with an erosion rate at the "T" value of 5.0 tons/ac-yr.

The observed increase in the rate of sediment accumulation in Lake Shafer appears to be the result of the loss of sediment trapping capacity in the watershed. Naturally occurring sediment traps in the Tippecanoe River drainage basin have filled with sediment over the years. As they have filled, their removal efficiencies have declined, and increasing amounts of sediment that would have otherwise been retained in the drainage basin have been transported downstream. The mouths of Big Monon Creek and Hoagland Ditch are examples of historically effective sediment traps.

An effective restoration program for Lake Shafer must address the two problems of increased sediment transport to the lake and unacceptable volumes of accumulated sediment already in the lake. The former problem may be addressed by ensuring that erosion control practices are implemented to the extent practical in the watershed, and through the renovation of historically effective sediment traps. The design and construction of new sediment traps will supplement existing traps. The mouth of Big Monon Dredge Ditch is a prime candidate for a constructed sediment trap.

The only solution to the accumulation of sediment that currently exists in Lake Shafer is a large-scale dredging project. Wet dredging techniques have several advantages that will make them attractive for this project, including cost and fact that the lake will not have to be drawn down. A drawdown is likely to result in unacceptably deleterious effects on uses of the lake, including tourism, fisheries, and the operation of Norway Dam.

Hydraulic dredging will probably provide the most cost effective wet method for removing the substantial volumes of sediment that will be required to be removed from Lake Shafer. A barge-mounted bucket dredge will probably be required for sediment removal in some of the confined embayments around the lake, as well as sediment traps at the mouths of Big Monon Creek and Hoagland Ditch. The cost of dredging the lake is anticipated to be in the range of $8.5 million and $14 million, based on a likely range of unit costs from $1.50 to $2.50 per cubic yard..

Sediment removal requirements for the renovation of existing sediment traps and construction of new traps in the watershed is impossible to estimate at this time. However, if it is assumed that the accumulated material in the lake (i.e., approximately 3,500 ac-ft.) would have been intercepted by these traps if they had been in place and working, then an equivalent amount of money may be required for this portion of the restoration project as for the in-lake effort. This is probably a conservative estimate.

6.2 SUGGESTED COURSE OF ACTION

A three-phase approach is part of the IDNR Lake Enhancement Program structure: 1) Feasibility Study, 2) Design, and 3) Implementation. This report provides the foundation for the these two phases.

6.2.1 Feasibility Study

The next step in the restoration of Lake Shafer should be a feasibility study with the following component tasks:

- Conduct a detailed review of soil erosion rates in the watershed to identify "hot-spots" where erosion is a problem and treatments may be implemented.
- Identify natural sediment traps and sites for constructed sediment traps in the watershed.

- Develop a watershed sediment transport model to serve as the basis for evaluating the placement of sediment traps and the sediment accumulation rates that may be expected in Lake Shafer. This effort will require the collection of suspended sediment data at critical locations in the watershed over a wide range of flow conditions.
- Develop estimates of trapping capacities, efficiencies, and rates for the identified sediment traps.
- Define an acceptable maintenance program for Lake Shafer, including intervals between major dredging operations.
- Develop estimates of sediment removal volume required to restore Lake Shafer's recreational value and provide sediment assimilation capacity over the maintenance interval.
- Collect lake and river basin sediment samples and analyze for EP toxicity.
- Collect lake sediment samples and quantify settling characteristics.
- Develop preliminary design requirements for the disposal site.
- Identify and evaluate suitable site(s) for settling basin and dredge spoil disposal. Slurry pipe routes should be included in this evaluation.
- Identify potential dredging contractors and develop confident estimates of costs for dredging lake and sediment traps.
- Identify all required permits for the proposed dredging program, contact the responsible agencies/authorities, and assemble required information to obtain permits.
- Identify, contact, and pursue potential sources of funding, including state and Federal grant programs, user fees, and bond issues (See Section 6.3).
- Design a monitoring program for assessing progress and environmental impact during and after the dredging.
- Develop a schedule for final design and implementation of the project.
- Establish funding package with commitments from contributing parties.

6.2.2 Design

The second phase of the restoration will be the design of the dredging and sediment trap construction. Final design efforts will include detailed layouts of the slurry pipeline, disposal site, and all necessary road improvements and modifications. Similarly detailed specifications will be developed for all sediment traps. The design effort will include finalization of the dredging and construction schedule, submittal of all required permit applications, receipt of approvals for these permits, and issuance of a request for bids to interested dredging companies. A request for proposals should be also issued for monitoring activities during and after the dredging effort.

6.2.3 Implementation

The last phase of the restoration program will be the actual sediment removal and sediment trap renovation/construction. A certain amount of final planning modifications should be anticipated after a dredging contractor has been identified. These activities may include development of a contractors work plan and safety plan, and finalization of monitoring protocols.

With regard to scheduling, the dredging activities should be planned and conducted to minimize impacts on tourism, local residents, the operation of Norway Dam, and biological communities in the lake. It is important that the positive impact of the restoration not be diminished by negative impacts that may be associated with large-scale dredging activities.

It is essential that a post-dredging monitoring program be planned and implemented as part of the restoration effort. The data collected will provide a means of measuring the success of the dredging activities and assessing the long-term response of the lake to the effort.

6.3 FUNDING

Lake restoration efforts are costly, and among the technologies used in restoration projects, dredging is one of the most expensive. Therefore it is crucial to the success of the Lake Shafer restoration that sources of funding be identified early in the planning process. The

U.S. EPA has recently published a guide to lake restoration efforts that includes a section on potential sources of funding (U.S. EPA, 1988). The discussion presented in this project report will serve to summarize the detail presented in the EPA document.

Funding sources for restoration projects are available at the Federal, state, and local level. At the Federal level, the EPA's Clean Lakes Program is probably the largest and best known sponsor of lake restoration efforts. The primary criteria for eligibility under the Clean Lakes Program are that the lake be accessible to the public; impacted by nutrient enrichment, sedimentation, acidification, or pollution from toxic substances; and that the restoration effort is coordinated among related governmental programs. Funding is available for Phase I (Diagnostic / Feasibility Studies) and Phase II (Implementation) management programs to improve lake water quality.

In addition to the Clean Lakes Program, a variety of Federal programs provide support to lake restoration projects. Table 5 presents a summary of Federal Programs that may be available to support the Lake Shafer project. Most grants or awards require a matching funds arrangement where the recipient is expected to provide some fraction of the total cost of restoration. These funds may be in the form of cash or in-kind services provided by the recipient organization, county, or state. An example is the contribution of state employees' labor to complete and submit permit forms.

Local funding sources include tax assessments, users fees, private foundations that foster certain aspects of lake management, and local organizations that can either provide contributions or sponsor fund-raising activities.

There are a number of institutional options that should be investigated as means of providing planning, funding, and political coordination in support of a restoration effort for Lake Shafer. One strategy is the formation of a Tippecanoe River basin commission, similar to those established for the Kankakee, St. Joseph, and Maumee River

TABLE 5. SUMMARY OF FEDERAL PROGRAMS THAT ARE AVAILABLE FOR LAKE RESTORATIONS

	Type of Program			
	Grants In Aid	Loan Guarantees	Technical Assistance	Information Services
DEPARTMENT OF AGRICULTURE				
Agricultural Stabilization and Conservation Service (ASCS)	●		●	
Cooperative Extension Service			●	●
Farmers Home Administration (FMHA)		●		
Forest Service	●		●	
Rural Development Loans		●		
Soil Conservation Service (SCS)	●		●	
DEPARTMENT OF COMMERCE				
Economic Development Administration (EDA)	●	●	●	
Minority Business Development Administration (MBDA)	●	●	●	
DEPARTMENT OF DEFENSE				
Army Corps of Engineers (COE)			●	
DEPARTMENT OF EDUCATION				
Environmental Education Program	●		●	
ENVIRONMENTAL PROTECTION AGENCY				
Clean Water Act [Water Quality Act of 1987 (WQA)] Section 104 (Demonstration Projects)	●	●	●	
Section 105 (Research and Development)	●			

TABLE 5. SUMMARY OF FEDERAL PROGRAMS THAT ARE AVAILABLE FOR LAKE RESTORATIONS (CONTINUED)

	Type of Program			
	Grants In Aid	Loan Guarantees	Technical Assistance	Information Services
Section 106 (Pollution Control-WWTP)	●			
Section 108 (Great Lakes Program)		●		
Section 201 (Local Management Plans)	●			
Section 208 (Areawide Management Plans)	●		●	
Section 314 (Clean Lakes Program)	●			
Section 319 (Nonpoint Source)	●			
FEDERAL EMERGENCY MANAGEMENT AGENCY				
Flood Plain Management	●			●
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT				
Community Development Block Grants	●			
Section 108 Loan Guarantees		●		
Federal Housing Administration (FHA)		●		
DEPARTMENT OF INTERIOR				
Bureau of Land Management (BLM)	●			
Office of Surface Mining and Reclamation	●	●		
U.S. Fish & Wildlife Service	●		●	●
U.S. Geologic Survey	●		●	●
Water Resources Protection Act	●			

TABLE 5. SUMMARY OF FEDERAL PROGRAMS THAT ARE AVAILABLE FOR LAKE RESTORATIONS (CONCLUDED)

	Type of Program			
	Grants In Aid	Loan Guarantees	Technical Assistance	Information Services
SMALL BUSINESS ADMINISTRATION				
Business Development and Assistance	●	●	●	●
DEPARTMENT OF TRANSPORTATION				
Federal Highway Administration (FHWA)	●			●

basins. These commissions were set up to address flooding issues, but their experience will be valuable in assessing the potential benefit of a similar commission for the Tippecanoe River. Another potential option would be the establishment of a Conservancy District under the IDNR Conservancy District Act. There are approximately 70 such districts currently in the state.

SECTION 7. REFERENCES

Buckler, J.H., T.M. Skelly, M.L. Luepke, and G.A. Wilken. 1988. Case Study: The Lake Springfield Sediment Removal Project. Lake and Reservoir Management, 4(1):143-152.

Carranza, C. and J. Walsh. 1985 Environmental Evaluation of Lake Dredging Projects in the Northeast. Lake and Reservoir Management - Practical Applications. North American Lakes Management Society. p 132-138.

Douglas, C. 1980. The Indiana Water Resource--Availability, Uses, and Needs. Indiana Department of Natural Resources.

Peterson, S. 1981. Sediment Removal as a Lake Restoration Technique. US EPA EPA 600/3-18-013.

Peterson, S. 1986 Lake Management Workshop. Lake and Reservoir Management, 2:433.

Stout, G.E. and M.J. Barcelona, 1983. Lake Sediments for Land Use Improvements. Lake Restoration, Protection, and Management. US EPA EPA 440/5-83-001. pp 8-12.

US EPA, 1988. The Lake And Reservoir Restoration Guidance Manual. U.S. EPA EPA 440/5-88-002.

APPENDIX A

OFFICES AND AGENCIES CONTACTED

Indiana Department of Environmental Management (IDEM)
- Office of Water Management
- Office of Technical Assistance
- Land Application Group - Permit Section
- Water Quality Surveillance
- Emergency Response
- Office of Solid and Hazardous Waste Management

Indiana Department of Natural Resources (IDNR)
- Div. of Water
- Div. of Fish and Wildlife
- Div. of Forestry
- Div. of Nature Preserves
- Div. of Outdoor Recreation
- Div. of State Parks
- Div. of Reservoir Management
- Map Sales Office
- State Geological Survey (Bloomington)
- Div. of Soil Conservation

Soil and Water Conservation Offices
- White County
- Pulaski County
- Jasper County
- Starke County
- Marshall County
- Fulton County
- Kosciusco County
- Whitley County
- Cass County
- Miami County
- Noble County
- State Office (Crawfordsville Road in Indianapolis)

Board of Health Offices
- White County
- Pulaski County
- Jasper County
- Starke County
- Marshall County
- Fulton County
- Kosciusco County
- Whitely County
- Cass County
- Miami County
- State Office in Indianapolis
- CTIC Office in W. Lafayette

Indiana Universities
  Indiana University
    School of Public and Environmental Affairs and Library
    Biology Department Library
    Geology Department Library
  Purdue University
    Department of Forestry and Natural Resources, Anne Specie
    Life Sciences Library
    Earth Sciences Library
    Water Resources Division at Life Sciences Building
    LARS, Dr. Johanason
    National Erosion Research Lab (Dept. of Agriculture)
  Tri-State University
    Department of Biology, Peter Hippensteel

Public Utility
  Northern Indiana Public Service Company

Conservation Groups
  Lake Maxinkuckee Environmental Council
  Hoosier Environmental Council in Indianapolis
  South Michiana Regional Planning Commission (South Bend)

U. S. Army Corp of Engineers
  Indianapolis Office
  Operations, Louisville Office

U. S. Geological Survey
  Div. of Water, state office in Indianapolis

APPENDIX B

ABSTRACTS OF REVIEWED DATA

WATER QUALITY DATA

IDEM Stream Segment 27 Survey

A segment survey was conducted of McKillip Ditch, Big Monon Creek, Big Monon Ditch, and the Ditch both above and below the Monon Municipal Waste Treatment Plant in July, 1979. Parameters measured included: Ammonia-N, BOD5, Chlorides, COD,, NO2 + NO3-N, pH(lab), Phosphorous, Solids-susp., Solids(total), Sulfate, and TKN. Data is on file on hard-copy at the Indiana Department of Environmental Management in Indianapolis.

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241
(317) 243-5028

IDEM Stream Segment 30 Survey

A survey was conducted on segment 30 of the Tippecanoe River Watershed during 1979 and is on file on hard-copy at the Indiana Department of Environmental Management in Indianapolis. The following parameters were measured: temperature, DO, pH, ammonia-N, BOD5, cadmium, arsenic, chlorides, chrome-H, chrome-T, COD, copper, iron-T, lead, manganese, nickel, NO2 & NO3/TKN, pH, phosphorous, suspended solids, total solids, sulfate, zinc, fluoride, and fecal coliforms.

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241
(317) 243-5028

IDEM Stream Surveys

The Indiana Department of Environmental Management, Office of Water Management conducts water quality surveys on streams throughout the state. Data from these surveys is published in "Water Quality Monitoring Rivers & Streams". The measurements are performed monthly and incorporate the following parameters: ammonia, BOD, chlorides, coliform, DO, nitrates, pH field, pH lab, phosphorous, total and suspended solids, specific conductivity, sulfate, temp., TOC, turbidity, and fecal streptococci. There are published data from four sampling sites on the Tippecanoe River.

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241
(317) 243-5028

STORET access information:

Station type=stream
Agency code=21IND
Station numbers:

TR-48	03331500	Tippecanoe River at Ora, 1957-1972.
TR-53	174017	Tippecanoe River at Winamac, 1971-72.

TR-145	174018	Tippecanoe River at Warsaw, 1971-72.
TR-107	174350	Tippecanoe River at Rochester, 1986-Current

STORET User Assistance Section

(800) 424-9067

(202) 382-7220

Indiana STORET Contact:

T.P. Chang
Technical Assistance
Department of Environmental Management
Chesapeake Building
105 South Meridian Street
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 232-8693

IDEM Kosciusco County Stream Report

During 1968-69 the Indiana Department of Environmental Management conducted a Kosciusco County Stream Report. The scope of the data ranged from simple biological habitat to water quality measurements which included: flow, DO, BOD, temperature, chlorides, alkalinity., pH, suspended solids, total solids, and coliforms. Included were measurements of the Warsaw Municipal Sewage Treatment Plant's effluent. This data is on hard-copy at the IDEM office in Indianapolis.

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241
(317) 243-5028

Mill Creek Bacteriological Survey

In response to suspected pollution problems at Mill Creek, the Fulton County Board of Health performed bacteriological tests. The data can be obtained on hard-copy in Rochester, Indiana at the county board of health.

Contact person:

Fulton County Board of Health
Wesley Burden, Sanitarian
802 Jefferson St.
Rochester, IN 46975
(219) 223-2881

Pulaski County Stream Surveys

The Pulaski County Board of Health monitored a couple of sites near Winamac to determine impacts of pollution. The data can be obtained on hard-copy in Winamac at the county board of health.

Contact person:

Pulaski County Board of Health
Betty Flora, Sanitarian
City County Building
125 S. Riverside Drive
Winamac, IN 46996
(219) 946-6080

National Eutrophication Survey

During the early to mid 1970's several Indiana lakes within the Tippecanoe River Watershed were included in the National Eutrophication Survey. The surveys included such lake characteristics like trophic condition, rate-limiting nutrient, nutrient controllability, lake and drainage basin characteristics, tributaries and outlets drainages, area, and mean flow. Parameters included: precipitation., temperature, DO, conductivity, pH, total alkalinity, total P, Ortho-P, NO2 + NO3, ammonia, TKN, inorganic N, total N, chlorophyll A, secchi disc, biological characteristics, N & P loadings. The data is available under the National Eutrophication Survey under the following STORET numbers:

1817 James Lake

1843 Lake Maxinkuckee

1844 Tippecanoe Lake

1837 Webster Lake

1840 Winona Lake

Washington Contact:

STORET User Assistance Section

(800) 424-9067

IDEM Lake Data

The Indiana Department of Environmental Management has a historical inventory of lake data. The scope of this data varies from simple coliform analysis to complete limnological surveys and can be obtained on hard-copy at Indianapolis. The lakes represented from the Tippecanoe Watershed are as follows:

Winona Lake	Coliform, 1969
Winona Lake	Limnological, 1970,69
Tippecanoe Lake	Coliform, 1969
Center Lake	Coliform, 1970
Winona Lake	Biological, 1969
Silver Lake	Limnological, 1968,69,60,62,64
Silver Lake	Coliform, 1970,66
Silver Lake	Biological, 1969
Hawks(Lost)Lake	Limnological, 1971,70
Lake Maxinkuckee	Limnological, 1985,82
Oswega Lake	Coliform, 1969
Palestine Lake	Limnological, 1976
Webster Lake	Limnological, 1976
Lake Shafer	Limnological, 1986,75

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241
(317) 243-5028

STORET Lake Data

US EPA has a comprehensive list of lake data available on STORET. The lake data was gathered by the Indiana Board of Health (now Indiana Department of Environmental Management, Water Pollution Control Division). These data can be obtained through STORET on hard-copy.

STORET access information:

Station type=lake
Agency code=21IND
Station numbers as follows:

350053	Upper Summit Lake, 1976
330052	Town Lake, 1976
350051	Zink Lake, 1976
350050	South Mud Lake, 1976
350049	Rock Lake, 1976
350048	Nyona Lake, 1975
350047	Mt. Zion Mill Pond, 1976
350046	Millark Mill Pond, 1976
350045	Lake Manitou, 1975
350044	Lake Sixteen, 1976
350043	King Lake, 1976
350042	Bruce Lake, 1976
350041	Fletcher Lake, 1976
350040	Barr Lake, 1976
350039	Anderson Lake, 1976
350080	Caldwell Lake, 1975

350078	Chapman Lake, 1975
350076	Big Barbee Lake, 1975
350075	Beaver Dam Lake, 1972-77
350074	Barrel Lake, 1974
350073	Backwaters Lake, 1975
350112	Sechrist Lake, 1975
350111	Sawmill Lake, 1975
350110	Rothenberger Lake, 1976
350109	Ridinger Lake, 1975
350108	Price Lake, 1974
350107	Pike Lake, 1975
350106	Muskelonge Lake, 1975
350105	Loon Lake, 1977
350088	Diamond Lake, 1977
350084	Daniels Lake, 1976
350083	Crystal Lake, 1975
350082	Center Lake, 1975
350081	Carr Lake, 1975
350104	McClures Lake, 1977
350103	Little Pike Lake, 1975
350102	Little Chapman Lake, 1975
350101	Kuhn Lake, 1975
350100	Little Barbee Lake, 1975
350099	Keyser Lake, 1976
350098	James Lake, 1975-77
350097	Irish Lake, 1975
350095	Hoffman Lake, 1975
350094	Hammond Lake, 1976
350093	Heron Lake, 1976
350092	Hill Lake, 1975
350091	Goose Lake, 1977
350128	Little Eagle Lake, 1976
350127	Yellow Creek Lake, 1976
350126	Webster Lake, 1975
350125	Winona Lake, 1976
350119	Tippecanoe Lake, 1975-77

350118	Stanton Lake, 1975
350115	Silver Lake, 1975-77
350114	Shoe Lake, 1975
350113	Shock Lake, 1974
350212	Lake Maxinkuckee, 1975-77
350248	Crooked Lake, 1974
350245	Crane Lake, 1974
350242	Big Lake, 1974
350240	Baugher Lake, 1977
350277	Smalley Lake, 1974
350271	Rider Lake, 1974
350260	Horseshoe Lake, 1974
350256	Harper Lake, 1974
350252	Gilbert Lake. 1974
350251	Durley Lake, 1974
350334	Hartz Lake, 1977
350335	Langenbaum Lake, 1977
350452	Little Crooked Lake, 1974

STORET User Assistance Section

(800) 424-9067

(202) 382-7220

Indiana STORET Contact:

T.P. Chang

Technical Assistance

Department of Environmental Management

Chesapeake Building

105 South Meridian Street

P.O. Box 6015

Indianapolis, IN 46206-6015

(317) 232-8402

Kosciusco County Lake Data

The Kosciusco County Health Department completes simple coliform analysis or more thorough limnological surveys on it's lakes. The data is available on hard-copy at the health department located in Warsaw, IN.

Contact people:

John Cupp, Chief Sanitarian
Bill Baxter, Deputy Administrator/Sanitarian
Kosciusco County Health Department
Court House, 3rd floor, Room 2
100 W. Center St.
Warsaw, IN 46580-2877
(219) 267-4444

Peter Hippensteel, Chairman of the Biology Department at Tri-State University, is conducting limnological surveys on lakes in Kosciusco County. Most of the lakes are in the Tippecanoe River Watershed and are listed. The analysis of these lakes also features some attention on non-point source pollution from erosion processes and the agricultural influences. Basic parameters include DO vs. depth profiles, nitrates, phosphates, coliforms, temperature, and suspended sediments. The data has been collected since 1983 through the summer of 1988 to determine any trends. A completed report is tentatively expected in November, 1988 and can be obtained from Peter Hippensteel at Tri-State University in Angola, Indiana.

Contact person:

Peter Hippensteel
Head of Biology Department
Tri-State University
Best Hall, Room 104A
Angola, IN 46703
(219) 665-4250

Lake Shafer Bacteriological Survey

The White County Department of Health has on file on hard-copy simple coliform data for Lake Shafer. This data is available in Monticello, IN.

Contact person:

John Pachmayr, Sanitarian
White County Department of Health
P.O. Box 838
White County Building
Monticello, IN 47960
(219) 583-8254

Lake Maxinkuckee Surveys

The citizens and temporary residents of Culver, Indiana created the Lake Maxinkuckee Environmental Council. This council was established in order to curtail the cultural eutrophication of Lake Maxinkuckee. The data can be obtained on hard-copy at their office in Culver, Indiana.

Contact person:

Karen L. Dehne, Executive Director
Lake Maxinkuckee Environmental Council
106 N. Main St.
Culver, Indiana 46511
(219) 842-3686

SEDIMENTATION STUDIES AND DATA

Lake Shafer Sediment Surveys: 1923 and 1940

Two sediment surveys were conducted on Lake Shafer in June, 1923 and August, 1940. The original reports are unavailable, but the summary data are presented in "Sediment Deposition in U.S. Reservoirs - Summary of Data Reported Through 1975," Miscellaneous Publication No. 1362, U.S. Dept. of Agriculture, Agricultural Research Service.

IDNR Lake Shafer Sediment Survey - 1954 (Uhl)

During Oct. 13-14, 1954 the Indiana Department of Natural Resources conducted a brief sediment survey of Lake Shafer during a lake drawdown. From this report, "soundings and cores were taken in several places. Rough estimations using such things as fence posts, tree stumps, boulders, were deemed to be sufficient criteria for determinations in many areas." Parameters measured were area of lake, watershed area, original capacity, capacity of lake in acres and acres feet, loss due to silting, annual loss, depth of station measurement, and type of sediment at station. The station locations can be determined with the help of large maps at the IDNR in Indianapolis where the report is available on hard-copy.

Contact person:

James T. Strange, C.P.G.
Engineering Geologist
Indiana Department of Natural Resources
Division of Water
2475 Directors Row
Indianapolis, Indiana 46241
(317) 232-4164

IDNR Lake Shafer Sediment Survey - 1983

The Indiana Department of Natural Resources (IDNR) conducted a sediment survey on August 23, 1983 during a lake drawdown. The depth of the water was compared to depth contours on a USGS topographic map. The depth contours were obtained from a USGS hydrographic survey dated Sept.-Oct., 1959 and May, 1960. This survey is available on hard-copy at IDNR, Division of Water in Indianapolis.

Contact person:

James T. Strange, C.P.G.
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Division of Water
2475 Directors Row
Indianapolis, Indiana 46241
(317) 232-4164

IDNR Lake Shafer Sediment Survey - 1986

The Indiana Department of Natural Resources (IDNR) conducted a sediment survey on December 5, 1986 during a lake drawdown. The parameters encompassed include: area of deposit, maximum thickness, shape factor, volume, storage capacity of the lake, and average annual sediment accumulation per square mile. The survey included some aerial photos which identify site locations. The data is on file on hard-copy at the IDNR office in Indianapolis.

Contact person:

James T. Strange, C.P.G.
Engineering Geologist
Indiana Department of Natural Resources
Division of Water
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Indianapolis, Indiana 46241
(317) 232-4164

USGS Stream Sediment Data

Some USGS sediment data is available on STORET. The data consist of measurements of sediment concentrations and distributions of sediment particle size at a station on the Tippecanoe River near Ora from 1968 through 1979. These data can be accessed through STORET in Washington or through the USGS publication "Suspended-Sediment Characteristics of Indiana Streams 1952-84".

STORET contact:

STORET User Assistance Section
(202) 382-7220
(800) 424-9067
Station Type=Stream
Agency Code=112wrd
Station number=03331500

STORET USGS Contact:

Arthur L. Putman
(703) 648-5687

USGS Publication:

USGS
Publications Sales
Denver Federal Center
Lakewood, CO 80225
(303) 236-7477

Lake Lemon Sedimentation Study

An investigation was conducted in 1973 by the Indiana Geological Survey on sedimentation in man-made Lake Lemon in southern Indiana. The results are presented in the Indiana Geological Survey technical report "Sedimentation in Lake Lemon, Monroe County, IN" by E. Hartke and J. Hill. This report describes techniques for sediment sampling and computations for determining lake volume. Sedimentation was found to be lower than expected in the lake. The report is available from the Indiana University Library at Bloomington, IN.

Big Monon Dredge Watershed Study

The White County Soil & Water Conservation District Board and the Soil Conservation Service studied the Big Monon Dredge Ditch watershed to estimate erosion rates and their potential impact on Lake Shafer. This study was stimulated by the 1983 sediment survey of the lake. Examination of the soils and landuse in the basin indicated that the weighted average erosion rate is 1.05 tons/ac-yr., well below the T value of 5 tons/ac./year.

"Suspended Sediment Characteristics of Indiana Streams."

An investigation was conducted by the U.S. Geological Survey analyzing suspended sediment data from daily and partial record stream stations collected between 1952 and 1984. The results are presented in the US Geological Survey Open-File Report 87-527, "Suspended Sediment Characteristics of Indiana Streams" by C. Crawford and L. Mansue (1988). The results indicated that suspended sediment concentrations were frequently largest during storms that were preceded by extended periods of low streamflow. This report is available through the Indiana Geological Survey.

Biological Data

Tippecanoe River Stream Surveys: 1972 and 1974

The Indiana Department of Natural Resources, Division of Fish and Wildlife has a report called "Tippecanoe River Stream Survey Report" by Robert Robertson. AC Electro-fishing and Rotenone sampling were used to weigh, measure, and scale sample fish. Also, water temperature, dissolved oxygen, pH, apparent color, bottom type, and evidence of erosion or pollution of stream were recorded. Surveys occurred in 1972 and 1974. The data are available on hard-copy at the Bass Lake State Fish Hatchery in Knox, Indiana.

Contact person:

Robert Robertson
Fish Management Biologist
Division of Fish and Wildlife
Bass Lake State Fish Hatchery
R.R. 3
Knox, Indiana 46534
(219) 772-2353

Lake Shafer Fish Surveys: 1975 and 1977

The Indiana Department of Natural Resources, Division of Fish and Wildlife conducted an initial survey in 1975, and a subsequent re-survey in 1977, both prepared by Bob Robertson. The number, percentage, weight, condition, and age of the fish were recorded. Lake parameters measured were surface area, max. depth, avg. depth, acre ft., water level, bottom type, alk. as calcium carbonate, total phosphates and nitrates, water color, secchi disk, water temp. vs. depth, DO vs depth, and pH. Also, common species of aquatic plants were recorded and gill netting was used. This data is available on hard-copy at the Bass Lake State Fish Hatchery.

Contact person:

Robert Robertson
Fish Management Biologist
Indiana Department of Natural Resources
Division of Fish and Wildlife
Bass Lake State Fish Hatchery
R.R. 3
Knox, Indiana 46534
(219) 772-2353

Lake Shafer, Lake Freeman, and Tippecanoe River Fish Surveys: 1976-81

The IDNR conducted "A Fisheries Survey of Lakes Freeman, Shafer, and the Tippecanoe River: Includes Fishing Pressure and Fish Harvest Surveys at Oakdale and Norway Dams." The surveys, collected by electroshocking, included the following parameters: number, percentage, weight, and age. These parameters were primarily measured in 1981 although some parameters were measured as early as 1976. Some stream quality parameters were measured during 1981 at the stations listed. The scope of these parameters included: air and water temp., avg. width and depth, shoreline vegetation, color, shade, aquatic vegetation, description of sample site, evidence of erosion or pollution, DO, pH, alkalinity, and concluding remarks. This data is available on hard-copy at the Bass Lake Fish Hatchery in Knox, IN.

Contact person:

Robert Robertson
Fish Management Biologist
Division of Fish and Wildlife
Bass Lake State Fish Hatchery
R.R. 3
Knox, Indiana 46534
(219) 772-2353

Lake Shafer and Tippecanoe River Watershed Fish Stocking Studies: 1983-85

The Indiana Department of Natural Resources, Division of Fish and Wildlife has a publication called "Evaluation of Hybrid Striped Bass Fingerling and Walleye Fry Stockings in Lake Shafer" by Bob Robertson. Two studies were conducted in 1984 and 1985. In each study, the fish were gill netted to determine number, relative abundance, length range, weight, and scales for age. Also water temperature, secchi depth, and DO were measured. The report is available from the author in Knox, Indiana.

Contact person:

Robert Robertson
Fish Management Biologist
Division of Fish and Wildlife
Bass Lake State Fish Hatchery
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Knox, Indiana 46534
(219) 772-2353

The Indiana Department of Natural Resources Division of Fish and Wildlife published "Evaluation of Walleye Fry and Hybrid Bass Fingerling Stockings in the Tippecanoe River Watershed, 1985". D.C. electro-fishing was conducted at two stations (Tippecanoe State Park and Winamac). Fish were identified and measured. Scale samples were taken from smallmouth bass. Other parameters measured were water temp., DO, and secchi disk.

Contact person:

Robert Robertson
Fish Management Biologist
Division of Fish and Wildlife
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Knox, Indiana 46534
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In an attempt to evaluate the growth and survival of the walleye and hybrid striped bass stocked in the Tippecanoe River and Lake Shafer in 1983 and 1984, six river stations from Tippecanoe River State Park to Buffalo were electro-fished during 1983 and 1984. The report "Evaluation of Walleye Fry and Hybrid Striped Bass Fingerling Stockings in the Tippecanoe River" by Bob Robertson, Fisheries Biologist, contains fish surveys which include relative abundance and size distribution of smallmouth bass. All fish collected were identified and measured. Also, water temperature, dissolved oxygen and secchi disk disk readings were measured at the stations. This data is available on hard-copy at the Bass Lake State Fish Hatchery in Knox, Indiana.

Contact person:

Robert Robertson
Fish Management Biologist
Division of Fish and Wildlife
Bass Lake State Fish Hatchery
R.R. 3
Knox, Indiana 46534
(219) 772-2353

IDEM Fishkill Data

The fishkills which occurred in the Tippecanoe Watershed were recorded from 1960 until June of 1988. The incidents were recorded by the affected stream and the nearest town (if available). These files are on hard-copy at the Indiana Department of Environmental Management (IDEM) at Indianapolis.

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241
(317) 243-5028

LANDUSE DATA

Miscellaneous Land Use Data (Incl. erosion)

These data consist of various county level summaries that are available from the County SCS offices, or the Conservation Technical Information Center at Purdue University.

- 1988 Conservation tillage practices by county.
- 1985 acres in cropland, pasture, & forest for Starke County.
- 1981 acres in cropland, pasture, & forest for Jasper, Newton, Pulaski, Starke, White, Fulton, Marshall, and Kosciusco counties.
- 1978 acres in cropland, pasture, & forest for Elkhart, Laporte, St.
  Joseph, Marshall, and Kosciusco counties.
- 1954 - 1978 acres in cropland, pasture, & forest for Marshall County

Erosion Potential Summaries

Several water and wind erosion potential summaries have been developed by the SCS and Indiana Department of Natural Resources (IDNR). County summaries of soil interpretations are available for Carroll, White, Jasper, Pulaski, Starke, Cass, Fulton, Marshall, and Kosciusco Counties from SCS.

H. Raymond Sinclair, Jr.
USDA, SCS
5610 Crawfordsville Rd., Suite 2200
Indianapolis, IN 46224

IDNR personnel developed an estimate of the weighted water erosion index for the Lake Shafer watershed. This was never published, but is in their files.

James T. Strange, C.P.G.
Engineering Geologist
Indiana Department of Natural Resources
Division of Water
2475 Directors Row
Indianapolis, Indiana 46241

Northeast Indiana Erosion Study

A study of soil erosion and sedimentation was conducted by SCS and INDR in 18 counties in northeastern Indiana. The results are presented as an overall report and individual county level reports published in 1988. County reports are available for Fulton, Cass, Kosciusco, Miami, Whitley, and Noble counties. Maps are provided showing areas where sheet, till, and gully erosion are a problem.

USDA, SCS
425 W. Northern Ave.
Logansport, IN 46947

County Soil Surveys

County level soil surveys have been prepared by the SCS for Cass, Whitley, Noble, Miami, Starke, White, Marshall, and Fulton counties. These detailed surveys present soil types, general soil associations, and characterizations of the soil types present in each county.

USDA, SCS
425 W. Northern Ave.
Logansport, IN 46947

Soil and Water Conservation Needs Inventory

The State Conservation Needs Committee, chaired by SCS, produced a summary report "Indiana Soil and Water Conservation Needs Inventory." (1968). The report presents land use by capability class and conservation treatment needs for 1967 by county.

State Conservationist

USDA, SCS

5610 Crawfordsville Rd., Suite 2200

Indianapolis, IN 46224

Water Resource Summary

IDNR published "The Indiana Water Resource--Availability, Uses, and Needs," (C.G. Douglas, 1980). This report presents regional characterizations of various aspects of water resources in the state. Maps are presented showing areas of high soil erosion potential.

Indiana Department of Natural Resources

605 State Office Building

Indianapolis, IN 46204

Library of Congress Catalog Card Number 79-620050

Natural Resources Inventory

The Indiana Soil Conservation Service has published the book "Indiana's Soil and Water: Natural Resources Inventory" (1987). This publication lists various natural resources parameters by geographic region. The information includes estimated land use percentages, average annual erosion in various land use categories, and conservation treatment needs.

NPDES Permits

National Pollution Discharge Elimination System permits issued by the Indiana Department of Environmental Management are on file at the IDEM office in downtown Indianapolis. Some permits are on micro-film, while most are as hard-copy only.

Contact person:

Lonnie Brumfield

Permits Section

Operations Branch
Department of Environmental Management
Office of Water Management
Chesapeake Building
105 South Meridian Street
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 232-8705

Feedlot Permits

The Indiana Department of Environmental Management oversees the land application of feedlots. Feedlots which require a permit must have at least 600 hogs, 300 cattle, or 30,000 poultry. A few feedlots do exist which have no permits but do meet the size requirement. Also, inspections of these feedlots do exist but occur infrequently; with the bulk of these inspections occurring in the 1970's. The feedlots listed are only those which have a permit and do not represent every feedlot in the Tippecanoe River Watershed. The permits are available on hard-copy in Indianapolis at IDEM.

Contact person:

Lee Parsons, Environmental Manager
Land Application Group, Permits Section
Operations Branch
Department of Environmental Management
Office of Water Management
Chesapeake Building
105 South Meridian Street
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 232-8732

Coal and Mineral Operations

The State Geological Survey of the Indiana Department of Natural Resources prepared a "Map of Indiana Showing Locations of Coal and

Industrial Minerals Operations". Active mines, pits, and quarries in 1980 are shown. The map is available from the State Geological Survey in Bloomington, IN.

Address:

Indiana Geological Survey
Publications Section
Geological Survey
611 North Walnut Grove
Bloomington, IN 47405

TOXIC CHEMICALS DATA

IDNR Lake Fish Tissue Analyses

The Department of Natural Resources conducted fish analysis for content of mercury, chlorinated hydrocarbons, dieldrin, and PCBs from a few Indiana Lakes. This data is available on STORET or through the Indiana contact. With the station number and the information listed below, this data can be obtained through STORET on hard-copy.

STORET access codes:

Station type=lake
Agency code=21INDR
Station numbers are as follows:

10Q	Beaver Dam Lake, 1971
R1239-2	Lake Maxinkuckee, 1972
R1239-35	Lake Shafer, 1972
R1239-26	Crooked Lake, 1972

STORET User Assistance Section

(800) 424-9067
(202) 382-7220

Indiana STORET Contact Person:

T.P. Chang
Technical Assistance
Department of Environmental Management
Chesapeake Building
105 South Meridian Street
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 232-8693

IDEM Fish Tissue and Sediment Samples

The Department of Environmental Management collected fish tissue and sediment samples from surface waters and lakes. The samples were analyzed for toxic metals and organics, depending on the specific concern at the sampling site. The original data sheets are located at the IDEM offices in Indianapolis.

Contact:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 West Bradbury
Indianapolis, IN 46241
(317) 243-5028

IDEM Chemical Spills Records

Indiana Dept. of Environmental Management maintains a record of all reported chemical spills in streams and lakes. The data are on STORET, and may be obtained, by stream segment, from IDEM in Indianapolis.

Indiana STORET Contact Person:

T.P. Chang
Technical Assistance

Department of Environmental Management
Chesapeake Building
105 South Meridian Street
P.O. Box 6015
Indianapolis, IN 46206-6015
(317) 232-8693

Warsaw Black Oxide Investigation

In response to problems associated with Warsaw Black Oxide, arsenic, cadmium, chromium, copper, lead, and mercury were measured downstream from the point of discharge from this industry. This data is available on hard-copy at the Indiana Department of Environmental Management in Indianapolis.

Contact person:

John L. Winters, Jr., Chief
Water Quality Surveillance and Standards Branch
Office of Water Management
Department of Environmental Management
5500 W. Bradbury
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MISCELLANEOUS STUDIES AND DATA

"Starke County Soil and Water Conservation District 1987 Conservation Tillage Demonstration Plot Information."

This report presents the study design and resulting data for an analysis of conservation tillage in demonstration plots.